EMERGING TECHNOLOGIES PROGRAM

INTEGRATION REPORT
VOLUME II

BACKGROUND, DELPHI AND WORKSHOP DATA

APPENDICES

PREPARED FOR
THE OFFICE OF THE DEPUTY UNDER SECRETARY OF DEFENSE, RESEARCH AND ADVANCED TECHNOLOGY

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The objective of the Emerging Technologies Program is to identify key technology areas of high interest to the DoD, for investment purposes. The two volumes of this integration report assess and synthesize information gathered through a Delphi survey, defense needs prioritization workshops, and assessments of high priority areas. Volume I of the report contains the actual narrative, analysis and assessments that have been developed; in Volume II are the background, Delphi and workshop data from which the analysis and assessments were drawn. The specific technologies considered are: command, control, and communications; directed energy; manufacturing; biotechnology; human factors; mobility; search and surveillance; and electronic warfare.

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BLOCK 18. ELECTRONIC WARFARE, SURVEILLANCE

EMERGING TECHNOLOGIES PROGRAM

INTEGRATION REPORT
VOLUME II

BACKGROUND, DELPHI AND WORKSHOP DATA

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APPENDIX 1

COMPLETED FASAC PANELS (AND DESCRIPTION OF FASAC PROGRAM)

APPENDIX 1
COMPLETED FASAC PANELS

FOREIGN APPLIED SCIENCES ASSESSMENT CENTER (FASAC)

For a number of years, the Intelligence Community paid little attention to broad analysis and assessment of foreign applied research and paid virtually no attention to basic research. This was due largely to the need to concentrate on analysis of present and near-term military threats, and the obvious technologies supporting them. To correct this inadequacy, in 1981 the Foreign Applied Sciences Assessment Center (FASAC) was established. Since its inception it has been operated by Science Applications International Corporation (SAIC).

The mission of FASAC is to improve US knowledge of the status and trends of foreign applied science and to increase awareness of newly emerging technologies with military, economic or political importance. Such knowledge can reduce the probability of technological surprise, can provide a background for US research and development decisions, and can assist the government in assessing the potential military, economic, or political implications of new developments. To accomplish this mission, the Center identifies, supports and guides panels of leading US scientists and engineers in the preparation of technical assessment reports and provides continuity as a national forum for periodic reviews of foreign science. Each FASAC report is an examination of research in a specific applied science area to assess the quality, quantity and direction of foreign research, to provide milestones for monitoring subsequent progress, and to measure the balance with US and/or Western research.

The key features of FASAC include: (1) use of expert panelists with current or recent "hands-on" research experience; (2) use of panelists who already have familiarity with the foreign research in their discipline; (3) use of the best qualified panelists from industry, government and/or universities, so as to provide a balancing of any biases toward "pet" research topics or approaches; (4) use of open, unclassified literature sources in a "bottom-up" analysis whose scope is defined mainly according to discipline; (5) providing panelists "time to think," typically six to eight months of in-depth analyses of literally thousands of foreign applied science references, analyses performed (part-time) at their home institutions; and (6) charging the panels to provide critical, professional analyses.

In the course of selecting panelists, who are key participants in US research programs, recommendations from corresponding government program managers are solicited and, in the process, these managers are made aware of FASAC activities. Also, further communication of the Center's work occurs through FASAC Workshops (discussed below) held to promote dialogue between the technically expert panelists and more broadly oriented representatives from the Intelligence and R&D user Communities.

Although the mission of FASAC is to examine foreign applied science, emphasis in the first four years has been placed on research in the Soviet Union. The Center reports on what the Soviets call exploratory research (akin to Department of Defense 6.1 and 6.2 programs), which seeks to translate developments in fundamental research into new technology. The Center does not generally report on technology already being incorporated in engineering applications nor does it generally deal with classified information.

As of May 1987, 18 FASAC panels addressing Soviet applied sciences have completed their work and 12 panels are in progress. Panel memberships and brief descriptions of the technical areas assessed by the first 18 panels are listed in this Appendix. Each panel produces a final report, the Technical Assessment Report (TAR). These reports strive to:

- Assess and describe research activities (including principal areas of emphasis) and the current state of the art achieved in the Soviet Union (and other countries, if appropriate) in a topical area.

- Identify the institutions and research teams that are doing the most significant research from a technical standpoint.

- Compare Soviet state of the art with US and world state of the art, trends in the level and intensity of effort (growing or waning), novel research approaches and techniques, and degree of access to research instrumentation, e.g., computers, as cross-cutting themes among panels.

- Extrapolate from current state of the art the future emerging technologies and applications that might have high military, economic or political impact, including considerations of technology transfer.

- Identify the milestones or subsequent achievements that the Soviets can be expected to attain in future research as checkpoints for later monitoring of progress in the field.

- Objectively, assess the impact and implications of Soviet research accomplishments (present and anticipated) for the United States.

- Identify areas of Soviet research which are outside an existing panel's focus, but which might be important for a future panel to address (e.g., serendipitous findings).

- Identify areas of research in which there is an anomalous absence of work in the technical literature--so called "resounding silences."

As indicated above, the panel's analysis is based largely upon critical, technical evaluation of the Soviet technical literature in the field, personal expertise and awareness of US and world research in the topical area, often coupled with insights gained from personal interactions with Soviet scientists. The reports are written in a style and at a level that can be understood by a reader with a general scientific-technical background. FASAC reports that have been completed to date, participating panelists, and sub-topics include:

(1) Soviet High-Pressure Physics Research

Dr. Marvin Ross, Chmn. (Lawrence Livermore Nat'l Lab.)
Dr. James Asay (Sandia Nat'l Labs.)
Dr. Francis Bundy (GE)
Mr. Robert Graham (Sandia Nat'l Labs.)
Dr. Forrest Rogers (Lawrence Livermore Nat'l Lab.)
Dr. James Schirber (Sandia Nat'l Labs.)

Static loading for super-hard machining materials and material properties and synthesis (metallic hydrogen); dynamic loading for strength properties (conventional and nuclear weapon effects) and material synthesis; equations of state for hot expanded metals and non-ideal plasmas.

(2) Soviet High-Strength Structural Materials Research

Dr. Maurice Sinnott, Chmn. (U. Michigan)
Mr. Michael Buckley (Rockwell Int'l)
Dr. Herbert Corten (U. Illinois)

Dr. Anthony Evans (U. California/Berkeley)
Dr. John Hirth (Ohio State U.)
Dr. Steven Tsai (Air Force Mat'ls Lab.)
Dr. James Williams (Carnegie-Mellon U.)

Development of new, certifiably resilient materials via applied research in fracture mechanics, nondestructive evaluation, microstructure and environmental effects.

(3) Soviet Applied Discrete Mathematics

Dr. Daniel Kleitman, Chmn. (MIT)
Dr. Richard Cottle (Stanford U.)
Dr. George Dantzig (Stanford U.)
Dr. Morris Marx (U. Oklahoma)
Dr. Robert McEliece (Cal. Tech.)
Dr. Oscar Rothaus (Cornell U.)

Mathematical programming (operations research); information theory (coding and communications); miscellaneous topics relevant to cryptography: complexity theory, combinatorics, graph & network theory, Boolean functions, modular arithmetic.

(4) Soviet Fast-Reaction Chemistry Research

Dr. Peter Rentzepis, Chmn. (U. California/Irvine)
Dr. Christos Capellos (US Army ARRADCOM)
Dr. David Crosley (Stanford Research Inst. Int'l)
Dr. Robert Frey (US Army Ballistic Research Lab.)
Dr. William Hoover (Lawrence Livermore Nat'l Lab.)
Dr. Marilyn Jacox (NBS)
Dr. B. Seymour Rabinovitch (U. Washington/Seattle)
Dr. Joel Schnur (NRL)
Dr. Leon Stock (U. Chicago)
Dr. K. David Straub (U. Arkansas)

Physical and biological processes, materials, synthesis and fast-spectroscopy studies (especially relevant to explosives and fuels), condensed-phase reactions, numerical modeling.

(5) Soviet Physical Oceanography Research

Dr. Michael Gregg, Chmn. (APL, U. Washington)
Dr. Thomas Sanford, Dep. Chmn. (APL, U. Washington)
Dr. Henry Abarbanel (Scripps, UCSD)
Dr. Melbourne Briscoe (Woods Hole)
Dr. Peter Niiler (Scripps, UCSD)
Dr. W. Brechner Owens (Woods Hole)
Dr. Clayton Paulson (Oregon State U.)
Dr. Norbert Untersteiner (APL, U. Washington)

Mesoscale circulation, air-sea interactions, ocean dynamics, internal waves, small-scale mixing processes, Arctic effects and experimental instrumentation.

(6) Soviet Computer Science Research

Dr. Carl Hammer, Chmn. (Sperry Univac, Ret'd)
Dr. Jacob Schwartz, Dep. Chmn. (New York U.)
Dr. Alfred Dale (U. Texas/Austin)
Dr. Michael Feldman (George Washington U.)
Dr. Seymour Goodman (U. Arizona)
Dr. William McHenry (U. Arizona)
Mr. Stephen Walker (Trusted Information Systems, Inc.)
Dr. Shmuel Winograd (T.J. Watson Research Center/IBM)

Theory and algorithms, compputer systems and networks, operating systems, programming language and software development, and information systems.

(7) Soviet Applied Mathematics Research: Mathematical Theory of Systems, Control, and Statistical Signal Processing

Dr. Sanjoy Mitter, Chmn. (MIT)
Dr. Roger Brockett, Dep. Chmn. (Harvard U.)
Dr. Dimitri Bertsekas (MIT)
Dr. Wendell Fleming (Brown U.)
Dr. Thomas Kailath (KF Concerns)
Dr. Israel Koltracht (Stanford U.)
Dr. Mark Levi (Boston U.)
Dr. Robert McGwier (Brown U.)

Dynamics and control theory for autonomous and controlled systems, stochastic dynamical systems, statistical signal and digital processing, filtering, and adaptive and control systems.

(8) Selected Soviet Microelectronics Research Topics

Mr. Jack Kilby, Chmn. (Consultant)
Dr. Lester Eastman, Dep. Chmn. (Cornell U.)
Dr. Robert Buhrman (Cornell U.)
Dr. James DiLorenzo (AT&T Bell Labs.)
Dr. Gerald Iseler (MIT Lincoln Labs.)
Dr. Ingolf Lindau (Stanford U.)
Dr. James McGarrity (Harry Diamond Lab.)
Dr. Donald Parker (Texas A&M U.)
Dr. Edward Poindexter (US Army/ETDL)
Dr. Thomas Seidel (AT&T Bell Labs.)
Dr. George Smith (AT&T Bell Labs.)
Dr. William Spicer (Stanford U.)

Materials, microanalysis, surface interfaces, epitaxy, energy processing, ion implantation, pattern definition, metallization, device/process design and circuit design for silicon and II-V semiconductors; radiation hardening processes, packaging, memory and novel-quasi-two-dimensional models for silicon; and Josephson Junctions.

(9) Soviet Macroelectronics (Pulsed Power) Research

Dr. Magne Kristiansen, Chmn. (Texas Tech U.)
Dr. James Benford (Physics Int'l)
Dr. Victor Granatstein (U. Maryland)
Dr. John Greenly (Cornell U.)
Dr. Arthur Guenther (AFWL)
Dr. Boris Levush (U. Maryland)
Dr. William Nunnally (Los Alamos Nat'l Lab.)
Mr. James O'Loughlin (AFWL)
Mr. Frank Rose (NSWC)
Dr. James Thompson (U. South Carolina)
Dr. Peter Turchi (R&D Associates)

Energy, storage, enery conversion/components, pulse-forming networks, switching, loads/applications, basic phenomena including dielectric breakdown and insulator flashover phenomena and nonlinear material effects, components (capacitors, inductors, transformers and resistors), diagnostics and radio frequency sources.

(10) Soviet Research on Robotics and Related Research on Artificial Intelligence

Dr. Alvin Despain, Chmn. (U. California/Berkeley)
Dr. Saul Amarel (Rutgers U.)
Dr. Takeo Kanade (Carnegie-Mellon U.)
Dr. Alexander Meystel (U. Florida)
Dr. Thomas Sheridan (MIT)
Dr. Delbert Tesar (U. Texas/Austin)

Decision making techniques, robot sensing systems, inspection systems, CAD/CAM, software algorithms, natural language text and higher order languages, machine handling and learning systems and adaptation.

(11) Soviet Applied Mathematics Research: Electromagnetic Scattering

Dr. Leon Peters, Chmn. (Ohio State U.)
Dr. Walter Burnside (Ohio State U.)
Dr. Chalmers Butler (U. Houston)
Dr. Benedikt Munk (Ohio State U.)
Dr. Prabhakhar Pathak (Ohio State U.)
Dr. Charles Ryan, Jr. (Georgia Tech Research Inst.)
Dr. Robert Stratten (U. Tulsa)
Dr. Donald Wilton (U. Houston)

Theoretical estimation and measurement of radar cross sections; control of scattered fields via vehicle shaping; use of appropriately designed absorbers; analysis/treatment of cavities and antennas; measurement of scattered fields and use of high resolution radars; study of scattered fields from second order scattering centers; asymptotic techniques for the analysis and control of scattered fields; integral equations for the analysis and control of component scattering.

(12) Soviet Low-Energy (Tunable) Laser Research

Chairman
Dr. Robert Byer (Stanford U.)

Dr. Larry DeShazar (Hughes Research Lab.)
Dr. Harold Fetterman (U. California/Los Angeles)
Dr. David Hinkley (JPL)
Dr. Charles Rhodes (U. Illinois/Chicago)

Excimer, dye, semiconductor and solid state crystalline lasers, far-infrared sources, and nonlinear frequency converters such as parametric oscillators and sum and difference frequency mixers.

(13) Soviet Heterogeneous Catalysis Research

Dr. Irwin Oppenheim, Chmn. (MIT)
Dr. James Carberry (U. Notre Dame)
Dr. Howard Davis (U. Minnesota)
Dr. Heinz Heinemann (Consultant)
Dr. George Keulks (U. Wisconsin/Milwaukee)
Dr. John Turkevich (Princeton U.)

Basic research on catalysts, including metals, oxides of transition metals, zeolites, and membrane catalysts; catalytic production of petrochemicals; petroleum and synthetic fuel catalysis; theoretical work on non-steady state reactions, fluctuating rate coefficients, diffusion in inhomogeneous media, oscillating chemical reactions, and chemical kinetics and catalysis; concepts and mechanisms of heterogeneous catalysis; and reactor design.

(14) Soviet Science and Technology Education

Dr. Robert Campbell, Chmn. (Indiana U.)
Dr. Harley Balzer (Georgetown U.)
Dr. Joseph Berliner (Brandeis U.)
Dr. Richard Dobson (USIA)
Dr. Paul Gregory (U. Houston)

Quality of science education; engineering education; utilization of personnel in S&T activities; structure and administration of Soviet education system; literacy, enrollments, degrees; S&T manpower trends; comparisons with the United States; secondary education; higher education; postgraduate education; orientation of research to significant problems; interinstitutional cooperation; research environment; Soviet S&T reward system; proposed school reform.

(15) Soviet Space Science Research

Dr. Louis Lanzerotti, Chmn. (AT&T Bell Labs.)
Dr. Richard Henry (Johns Hopkins U.)
Dr. Harold Klein (U. California/Santa Clara)
Dr. George Paulikas (Aerospace Corp.)
Dr. Frederick Scarf (TRW)
Dr. Gerald Soffen (Goddard Space Flight Ctr.)
Dr. Yervant Terzian (Cornell U.)

Solar-terrestrial physics (solar physics, interplanetary medium, magnetospheric physics, ionospheric physics, physics of the upper atmosphere); lunar and planetary space research; space astronomy and astrophysics (gamma-ray astronomy, cosmic

rays, x-ray astronomy, ultraviolet astronomy, optical and infrared astronomy, radio astronomy, SETI); life sciences.

(16) Soviet Tribology Research

Dr. Kenneth Ludema, Chmn. (U. Michigan)
Dr. James Barber (U. Michigan)
Dr. Richard Fein (Consultant)
Dr. Howard Leavenworth (US Bureau of Mines)
Mr. Robert Maurer (SKF Industries, Inc.)
Dr. Paul Sutor (Midwest Research Inst.)

Contact mechanics; lubrication and lubricants; mining and mineral processing, bearing technology; advanced technologies; fundamentals of tribology, wear.

(17) Japanese Applied Mathematics Research: Electromagnetic Scattering

Dr. Chen-To Tai, Chmn. (U. Michigan)
Dr. Robert Collin (Case Western Reserve U.)
Dr. Ivan LaHaie (ERIM)
Dr. Yu-Ping Liu (Northrup Corp.)
Dr. Allan Love (Rockwell Int'l)
Dr. Edmund Miller (Lawrence Livermore Nat'l Lab.)
Dr. Thomas Senior (U. Michigan)
Dr. W. Ross Stone (IRT Corp.)

RCS reduction; scattering and diffraction (direct and inverse, application to RCS reduction); numerical methods relevant to RCSR; antennas (elementary, arrays, reflector, satellite, measurements); microwave theory and techniques.

(18) Soviet Combustion Research

Dr. William McLean, Chmn. (Sandia Nat'l Labs.)
Mr. Charles Amann (General Motors Research Labs.)
Dr. C. T. Bowman (Stanford U.)
Dr. Paul Libby (U. California/San Diego)
Dr. Richard Palmer (Sandia Nat'l Labs.)
Dr. L. Douglas Smoot (Brigham Young U.)
Dr. Roger Strehlow (U. Illinois)

Combustion chemistry (gaseous combustion); theory of laminar and turbulent reacting flows (foundations of modeling, gas phase laminar and turbulent flames); advanced diagnostics and instrumentation (laser-based probes); solids combustion (FBC, conventional pulverized fuel firing); heat engine combustion (modeling, supersonic, emissions, alternative fuel utilization); combustion safety and practical systems (gaseous and liquid fuel combustion, catalytic).

FASAC REPORT TOPICS (in production)

Soviet Spacecraft Engineering Research
Soviet Exoatmospheric Neutral Particle Beam Research
Soviet Research in Remote Sensing Technology
Soviet Research in Fracture Mechanics

Soviet Image and Pattern Recognition Research
Soviet Magnetic Confinement Fusion Research
Soviet Microelectronics Research (Update)
Soviet Ionospheric Research
Soviet High Power/RF Sources Research
Chinese Microelectronics Research
Free-World Microelectronics Research
System Software for Soviet Computers

FASAC REPORT TOPICS (proposed)

Japanese Ceramics Research
Soviet Phase-Conjugation Research
Soviet Research in Low-Observable Materials

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APPENDIX 2
COMPLETED JTECH PANELS (AND DESCRIPTION OF JTECH PROGRAM)

APPENDIX 2
COMPLETED JTECH PANELS

JAPANESE TECHNOLOGY EVALUATION PROGRAM (JTECH)

The Japanese Technology Evaluation Program (JTECH) is operated for the Federal Government by Science Applications International Corporation to provide definitive technical assessments of emerging Japanese capability in selected high-technology areas. The JTECH program was initiated in September 1983 by the Department of Commerce; currently, the National Science Foundation, is the lead support agency. The JTECH program evaluations are intended to serve as a sound technical basis for allowing proper responses to the Japanese challenge, particularly with respect to providing technical input for potential users charged with making technology forecasts, preparing competitive assessments, determining viable US industry responses to the Japanese challenge and establishing directions for US trade policy.

The assessments are performed by panels of US technical experts with about six panel members for each subject area. Panel members are all leading technical authorities in the field in question; many have had direct experience with Japanese research programs and technology. Each panel member devotes approximately one person-month to literature review, assessments and report writing on a part-time basis over a period of about six months. To balance perspectives, panel members are drawn from the academic, research, government and industrial communities.

The main focus of the assessments is the current status and long-term direction and emphasis of Japanese research and development efforts. Other important aspects include the background evolution of the state-of-the-art; key Japanese researchers, R&D organizations, and resources; and comparative US efforts. The general time frame of the R&D forecasts is 10 years, corresponding to future industrial applications and commercial effects five to 20 years ahead. Subtopics within a particular area are selected primarily on the basis of expected commercial impact of the Japanese R&D on US industry.

SAIC provides Japanese S&T literature and translation services to the panelists. Special efforts are made under the JTECH approach to provide panelists with timely semi-open source material, such as informal proceedings from ad hoc seminars and conferences in the Japanese high-tech community, results from recent technical

committee meetings on national Japanese R&D projects, and from contacts at R&D centers in Japanese high tech industries. Literature requests and dissemination of technical material are continuous and interactive throughout the course of the assessment.

(1) Computer Science in Japan

Mr. David Brandin, Chmn. (SRI Int'l)
Dr. Jon Bentley (AT&T Bell Labs.)
Dr. Thomas Gannon (Digital Equipment Corp.)
Dr. Michael Harrison (U. California/Berkeley)
Dr. John Riganati (NBS)
Dr. Frederic Ris (T.J. Watson Research Ctr./IBM)
Dr. Norman Sondheimer (U. Southern California, Information Sciences Inst.)

Software engineering/applications, artificial intelligence and man-machine interface including machine translation, Japanese character processing, MITI's Fifth Generation Computer Systems, super computers, parallel processing, and communications.

(2) Mechatronics in Japan

Mr. James Nevins, Chmn. (Charles Stark Draper Lab.)
Dr. James Albus (NBS)
Dr. Thomas Binford (Stanford U.)
Dr. J. Michael Brady (MIT)
Mr. Michael Kutcher (IBM)
Dr. P. J. MacVicar-Whelan (Boeing AI Ctr.)
Dr. G. Laurie Miller (AT&T Bell Labs.)
Mr. Lothar Rossol (GMF Robotics)
Mr. Karl Schultz (Cincinnati-Milacron)

Flexible Manufacturing Systems (FMS), assembly/inspection systems, sensors (including vision and non-vision sensor systems), intelligent modules/autonomous machines, software for mechatronics, manipulator/actuators, and precision mechanisms.

(3) Opto- & Microelectronics in Japan

Mr. Harry Wieder, Co-Chmn. (U. California/San Diego)
Dr. William Spicer, Co-Chmn. (Stanford U.)
Dr. Robert Bauer (Xerox Corp.)
Dr. Federico Capasso (AT&T Bell Labs.)
Dr. Douglas Collins (High-Speed Devices Lab./Hewlett-Packard)
Dr. Karl Hess (U. Illinois)
Dr. Harry Kroger (MCC Corp.)
Mr. Robert Scace (NBS)
Dr. Won-Tien Tsang (AT&T Bell Labs.)
Dr. Jerry Woodall (T.J. Watson Research Ctr./IBM)

Organization of the Japanese effort on non-silicon based opto- and microelectronics, synthesis of compound semiconductor materials, properties and applications of

multiquantum well and superlattice structures, solid state lasers in the near IR and visible regions of the spectrum, avalanche detector and optoelectronic integrated circuits research, equipment and manufacturing techniques, and Josephson devices and technology (including comparison of the Japanese and US Josephson programs).

(4) Biotechnology in Japan

Dr. Dale Oxender, Chmn. (U. Michigan)
Dr. Charles Cooney (MIT)
Dr. David Jackson (Genex Corp.)
Dr. Gordon Sato (W. Alton Jones Cell Science Ctr.)
Dr. Reed Wickner, M.D. (NIH)
Dr. John Wilson (Lord Corporation/Research Triangle area)

Genetic information transfer, biochemical process technology, biosensors, large scale tissue culture in hybridoma industrial activity, protein engineering, recombinant DNA applications, and predictions of future trends in biotech research.

(5) Telecommunications in Japan

Dr. Dean Turin, Chmn. (U. California/Los Angeles)
Dr. William Davidson (U. Southern California/Los Angeles)
Dr. Paul Green, Jr. (IBM Research Ctr.)
Dr. James Mikulski (Motorola)
Mr. Albert Specer, Jr. (AT&T Bell Labs.)
Dr. Bruce Woodley (Stanford U.)

Devices and chips, systems (switches, PBX, modems, Codecs), networks (LAN and ISDN, SATNETS, etc.), RF applications (mobile nets, paging teletex, etc.).

(6) Advanced Materials in Japan

Dr. James Economy, Chmn. (San Jose Labs./IBM)
Dr. Michael Jaffe (Celanese Research Co.)
Dr. William Koros (U. Texas/Austin)
Dr. Raphael Ottenbrite (Virginia Commonwealth U.)
Dr. Elsa Reichmanis (AT&T Bell Labs.)
Dr. John Schaefgen (DuPont Textile Fibers Pioneering Research Lab., ret'd)

Polymers for filtration processes, high-performance polymers (matrix), biopolymers, electronic polymers, high-strength/modular polymers.

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APPENDIX 3

DELPHI ROUND 1 QUESTIONNAIRE

APPENDIX 3

DELPHI ROUND 1 QUESTIONNAIRE

INTRODUCTION

The rate of technological development has accelerated dramatically since World War II; the time between basic discovery and practical application turns out to be impressively short in many areas, though there are counterexamples of predicted breakthroughs that have failed to occur on schedule. At the same time, the United States, once a clear leader in most areas of technology, has been faced with increasing competition from other nations and can no longer be assured that it can continue to dominate the world in new technological developments and their application. During the 1980s and beyond, explosive growth is predicted in almost all technological areas and it is incumbent upon the US Government to understand this growth and have the ability to forecast the most significant events. The US Department of Defense in particular has the responsibility to identify those areas of largest potential impact upon national security and take appropriate action to assure that the US does not fall behind in some critical area.

To help construct a clearer picture of the future, a Delphi survey is being undertaken to identify technologies that are or may soon be emerging from the basic proof-of-principle stage to eligibility for inclusion in a production process or product. In this survey of emerging technologies, we are particularly focusing on developments that are not yet recognized by many as having significant potential impact. These would include ideas that are still in the research stage and with additional funding or breakthrough will become important for commercial and/or military applications. We are also interested in rapidly advancing technologies that have been recognized as potentially important, since their developments are moving extremely fast, thus requiring careful monitoring for new opportunities.

Some examples might be useful at this point. Back in 1980, the free electron laser was an example of a potential "emerging technology" for which the time scale of development was uncertain, while Gallium Arsenide Integrated Circuit Technology was perceived to be a "rapidly advancing technology." In the former, the recognition of potential was not widespread, and much more work was needed to see if a scale-up was possible. The GaAs I.C. technology was moving very rapidly and it was generally recognized that its impact could be very large. Right now, the FEL is more generally recognized as a significant emerging technology, while the GaAs I.C. is recognized as in fact available for some applications but has not replaced silicon technology; it thus bears further watching and nurturing as appropriate.

DELPHI FORECAST MECHANICS

This is the first in a series of three or four questionnaires in a Delphi study, in which you have agreed to participate as a respondent. The Delphi forecast is the initial phase of a program being initiated by Science Applications International Corporation (SAIC) on behalf of the US Department of Defense. This forecast will be followed by in-depth studies in several of the areas identified as having the highest priority based on national security considerations.

To be useful, Delphi forecasts require the cooperation of many people. This technological forecast is no exception and the sponsors and authors wish to thank the participants for agreeing to devote time away from their busy schedules to participate in this endeavor.

The responses you and others will give to these questionnaires will be handled strictly anonymously, in the sense that no response will be attributed by name to any particular respondent. Each questionnaire, after the first, will provide you with a summary of responses received in the preceding round. Only in the final report on the outcome of this survey will the names of the participants be listed (but again without specific attribution).

In order to expedite the conduct of this exercise, may we urge you to mail your responses within two or three days after receiving this questionnaire. An envelope for this purpose has been provided. You may expect to receive the next questionnaire around the middle of February. If, at the time, you will not be at your regular address, please indicate where that questionnaire should be addressed.

This questionnaire is being sent to a select group of twenty-five participants. You are being asked to identify: (1) one or more general technology areas that should now merit aggressive research funding (federal and/or private); and, (2) five or more specific technological developments that are likely to emerge from concept to "technology on the shelf" in the next fifteen years. The replies will then be integrated and sent out to a larger group of respondents, including you, for their comments. The larger group will be asked to comment on the initial list and add new entries.

The following pages contain the two questions, with illustrative examples of responses, plus additional sheets for your own use.

QUESTION 1 (Example)

What general technology area or areas do you feel now merit aggressive research funding, because of the possible emergence of important applications by the end of this century? Please list, as appropriate, subareas within the general area that deserve or need special attention.

A) Area/Subareas

Robotics
- Robotic vision
- Robot kinesthetics
- Accurate robotic motion and positioning
- Robot computer architecture/microprocessors

B) Potential Applications

Manufacturing, materials handling, novel systems for reconnaissance and targeting

C) Rationale for success

Ongoing developments in VHSIC and electro-optics sensor technology can provide some key elements that could be integrated into intelligent, independent robotic systems.

QUESTION 1(a)

What general technology area or areas do you feel now merit aggressive research funding, because of the possible emergence of important applications by the end of this century? Please list, as appropriate, subareas within the general area that deserve or need special attention.

A) Area/Subareas

B) Potential Applications

C) Rationale for success

QUESTION 1 (b)

What general technology area or areas do you feel now merit aggressive research funding, because of the possible emergence of important applications by the end of this century? Please list, as appropriate, subareas within the general area that deserve or need special attention.

A) Area/Subareas

B) Potential Applications

C) Rationale for success

QUESTION 1(c)

What general technology area or areas do you feel now merit aggressive research funding, because of the possible emergence of important applications by the end of this century? Please list, as appropriate, subareas within the general area that deserve or need special attention.

A) Area/Subareas

B) Potential Applications

C) Rationale for success

QUESTION 2(Example)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

Free electron lasers operating in the optical to mid IR ($< 10\mu$) with high efficiency at moderate power levels ($\sim$ kilowatt).

B) Potential Applications

Laser radar, optical communications, remote sensing, etc.

C) Why do you think it is possible?

FELs at longer wavelengths are being demonstrated to have good efficiencies. There is a need for increasing the effective undulator spatial frequency; this could involve the use of solids with periodic domain structures.

QUESTION 2 (a)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

B) Potential Applications

C) Why do you think it is possible?

QUESTION 2 (b)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

B) Potential Applications

C) Why do you think it is possible?

QUESTION 2 (c)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

B) Potential Applications

C) Why do you think it is possible?

QUESTION 2 (d)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

B) Potential Applications

C) Why do you think it is possible?

QUESTION 2(e)

What specific technological developments could be made to emerge from the concept stage to a maturity sufficient to be available for significant applications within the next fifteen years or less? The developments we are looking for should be more specific than the answers to Question 1, as illustrated by the example.

A) Description of Technology

B) Potential Applications

C) Why do you think it is possible?

APPENDIX 4
DELPHI ROUND 2 QUESTIONNAIRE

APPENDIX 4

DELPHI ROUND 2 QUESTIONNAIRE

INTRODUCTION

This is the second in a series of three or four questionnaires in a Delphi study, in which you have agreed to participate as a respondent. Some of you were respondents to the first questionnaire. The Delphi forecast is the initial phase of a program being initiated by Science Applications International Corporation (SAIC) on behalf of the US Department of Defense (DoD). The purpose of this program is to help DoD identify technologies that are or may soon be emerging from the basic proof-of-principle stage to eligibility for inclusion in a production process or product. In this survey of emerging technologies, we are particularly focusing on developments that are still in the research stage, and not yet well recognized as having significant military and/or commercial applications. We are also interested in rapidly advancing technologies that have already been recognized as potentially important, but where developments are fast, requiring careful monitoring for new opportunities. This forecast will be followed by in-depth studies in several of the areas identified as having the highest priority based on national security considerations.

The responses you and others will give to these questionnaires will be handled strictly anonymously, in the sense that no response will be attributed by name to any particular respondent. Only in the final report on the outcome of this survey will the names of the participants be listed (but again without specific attribution).

In order to expedite the conduct of this exercise, may we urge you to mail your responses within two or three days after receiving this questionnaire. An envelope for this purpose has been provided. You may expect to receive the next questionnaire late in April. If, at that time, you will not be at your regular address, please indicate where that questionnaire should be addressed:

INSTRUCTIONS FOR COMPLETION OF QUESTIONNAIRE NO. 2

This questionnaire contains a listing of promising technologies, derived from the responses to the previous questionnaire (No. 1). Since the first questionnaire was circulated to only some of you, we expect that most respondents will wish to add items that they consider of importance comparable to those listed. The new items will be circulated to all respondents in the next round.

In addition to adding more items, you are being asked to make two judgements with respect to the listed (or added) items. First, please indicate your rating of the relative value of the items on the following crude scale:

0 = unimportant
1 = possibly of some importance
2 = of average importance
3 = of greater than average importance
4 = very important; outstanding value

Importance is defined in terms of your view of the significant applications that could ensue in areas important to US national security (in the broadest sense).

Second, please make an estimate of the time interval during which the advance might be expected to have reached the stage of <u>availability</u> for inclusion in a product, process, or military system. "Availability" presumes a successful demonstration of the technology. The times are specified in 5-year intervals from now over the next twenty years.

Because of the wide span of technologies encompassed, you may not feel qualified to answer the questions in some areas. If so, please check the "prefer not to answer" column. The questionnaire is broken into categories of roughly similar technologies, for your convenience. In making additional entries, do not feel constrained to the listed categories. We are looking for your suggestion of any and all areas that you feel may become important.

CANDIDATE TECHNOLOGIES - 1

Technology	VALUE	AVAILABILITY: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
COMPUTERS									
1. Automatic generation of software from "natural language"									1.
2. Parallel processing based on cosmic cube architecture									2.
3. Architecture based on neuron connectivity in mammalian brains									3.
4. Very fast, small, inexpensive read-and-write memories									4.
MICROELECTRONIC MATERIALS									
5. Synthetic nonlinear optics materials custom-designed for specific applications (e.g., optical computer elements)									5.
6. Integrated sensors on an electronic chip for measurement of pressure, temperature, acceleration									6.
7. Molecular-scale electronic circuit elements and conductors.									7.
8. Integrated optical sensors/digital processing elements in a single chip focal plane array.									8.
9. Synchrotron radiation source X-ray lithography									9.
10. Growth of 3 and 4 components compound semiconductors of desired (specified) characteristics									10.
OPTICS, LASERS									
11. Ultra low-loss fiber optics									11.
12. Sub-wavelength optical imaging by gradient techniques									12.

CANDIDATE TECHNOLOGIES - 2

	VALUE	AVAILABILITY: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
OPTICS, LASERS (continued)									
13. Optical fiber sensors for measurement of physical parameters									13.
14. Optical fiber sensors for measurement of chemical properties									14.
15. Real-time holographic interferometry through fiber optics									15.
16. Coherent gamma-ray sources (e.g., X-ray lasers)									16.
17. Steerable laser diode arrays at powers of ~ 1 kw/cm^2									17.
18. Rare-gas halide excimer lasers with high efficiency and high energy output									18.
19. Nd: YAG lasers with average power greater than 1 kw, for manufacturing									19.
20. CO_2 lasers for manufacturing with power greater than 10 kw									20.
21. Steerable laser diode arrays at powers of ~ 1 kw/cm^2									21.
DIRECTED ENERGY TECHNOLOGY									
22. High-current radiofrequency quadrupole accelerators									22.
23. Reusable opening switches for very high power (10^{10} - 10^{12}w), high voltage (~ MV), ~ nsec rise times									23.
CHEMISTRY, CATALYSIS AND ENERGY PRODUCTION									
24. Physical separation of gases or liquids by means of hollow fibers or affinity chromatography									24.
25. Use of therwite combustion reactions to wake high temperature materials									25.

CANDIDATE TECHNOLOGIES - 3

	VALUE	AVAILABILITY						Prefer not to answer	
		1985	1986-1990	1991-1995	1996-2000	2001-2004	2005-never		
<u>CHEMISTRY, CATALYSIS AND ENERGY PRODUCTION</u> (continued)									
26. Laser synthesis of energetic molecules									26.
27. Elimination of soot formation in military engines									27.
28. Spark-ignited diesel engines, permitting use of a wide spectrum of fuels									28.
29. Methanol production from atmospheric CO_2 using solar energy									29.
30. Near-adiabatic diesel engines utilizing high-temperature ceramic components (and no circulating coolant)									30.
31. Bio-catalysis with immobilized enzymes									31.
32. Compound synthesis by solar photo-electrochemistry									32.
<u>ROBOTICS, AUTOMATION, AND MACHINE INTELLIGENCE</u>									
33. Automated image recognition and classification through use of AI techniques									33.
34. Autonomous machine vision for robot self-guidance and/or industrial inspection									34.
35. Autonomous weapons vision with automatic target recognition									35.
36. Development of a working model of optimum allocation of decisions and actions between humans and machines in a man-machine system									36.
37. Automatic recognition of speech									37.
38. Automatic understanding of speech of a specific individual									38.

CANDIDATE TECHNOLOGIES - 4

	VALUE	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
39. Automatic understanding of speech of a general class of individuals									39.
40. Automated chemical analysis using robotics, for laboratory or manufacturing plant									40.
MACROSCOPIC MATERIALS									
41. Conducting polymers for "all-plastic" batteries and light-weight electronics									41.
42. High-permeability rare earth permanent magnet systems for low-cost rotating machinery, accelerators, etc									42.
43. Fiber-reinforced ceramics for high-strength applications at high temperatures									43.
44. Development of fundamental understanding of materials surface preparation, including interface physics and chemistry on the atomic scale									44.
45. Practical application of ion implantation and/or high energy laser irradiation to produce hard, wear and corrosion-resistant surfaces									45.
46. Metal matrix composites for high strength-to-weight									46.
47. Rapid solidification processing of high-strength materials									47.
48. High-energy laser welding of structures or structural components									48.
BIOTECHNOLOGY									
49. Blood surrogates for universal transfusability, competitive with natural product									49.
50. Therapeutic materials incorporating neurotransmitters for improving human benavior and performance									50.

CANDIDATE TECHNOLOGIES - 5

	VALUE	AVAILABILITY: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
BIOTECHNOLOGY									
51. Therapeutic materials for control of human immune response in treatment of diseases									51.
52. Drugs effectively targeted against specific cell types (e.g., cancer cells) with sustained release									52.
53. Development of organisms that will metabolize toxic waste products									53.
54. Development of organisms that will counter the biodegradation of structures									54.
55. Development of design rules and engineering principles for synthesis of proteins with desired properties									55.
FLUID DYNAMICS									
56. Underwater drag reduction via boundary layer control or modification									56.
REMOTE SENSING AND INSTRUMENTATION									
57. NMR imaging for investigation of structural and mechanical properties of composite materials									57.
58. Airborne/spaceborne laser radars (eye-safe) for remote sensing of global atmospheric properties									58.
59. Acoustic imaging for reconnaissance of the interiors of structures and nondestructive testing									59.
60. Microwave mapping of wind speed at the sea surface from satellite radar.									60.

CANDIDATE TECHNOLOGIES - 6

	VALUE	AVAILABILITY: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
REMOTE SENSING AND INSTRUMENTATION (continued)									
61. Doppler weather radar (airborne) for storm and wind tracking and warning									61.
SYSTEMS AND CONCEPT DEMONSTRATIONS									
62. Development and demonstration of design principles for substantially improved reliability of weapons systems									62.
63. Development of unmanned, remotely addressable underwater vehicles									63.
64. Unmanned fighter aircraft									64.
65. Development of single integrated "all-weather" visual displays for use by aircraft operator									65.

CANDIDATE TECHNOLOGIES -

	VALUE	AVAILABILITY: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer

(blank)

APPENDIX 5

DELPHI ROUND 3 QUESTIONNAIRE

(Introduction Only; Remainder at Appendix 6)

APPENDIX 5

DELPHI ROUND 3 QUESTIONNAIRE

(Introduction Only; Remainder at Appendix 6)

INTRODUCTION

This is the third questionnaire in a series of four (including the Test group questionnaire) in a Delphi study, in which you have agreed to participate as a respondent. All of you were respondents to the previous questionnaire. In this round, we are focusing on your previous responses and will be trying to reach a consensus on a number of them. We will also be trying to eliminate some entries.

The Delphi forecast is the initial phase of a program being initiated by Science Applications International Corporation (SAIC) on behalf of the US Department of Defense (DoD). The purpose of this program is to help DoD identify technologies that are or may soon be emerging from the basic proof-of-principle stage to eligibility for inclusion in a production process or product. In this survey of emerging technologies, we are particularly focusing on developments that are still in the research stage, and not yet well recognized as having significant military and/or commercial applications. We are also interested in rapidly advancing technologies that have already been recognized as potentially important, but where developments are fast, requiring careful monitoring for new opportunities. This forecast will be followed by in-depth studies in several of the areas identified as having the highest priority based on national security considerations.

The responses you and others will give to these questionnaires will be handled strictly anonymously, in the sense that no response will be attributed by name to any particular respondent. Please indicate here whether you are willing to have your name listed in our final report as a participant in this survey:

YES [ ]

NO [ ]

In order to expedite the conduct of this exercise, may we urge you to mail your responses within two or three days after receiving this questionnaire. An envelope for this purpose has been provided.

INSTRUCTIONS FOR COMPLETION OF QUESTIONNAIRE NO. 3

This questionnaire contains a listing of promising technologies, derived from the responses to the previous questionnaires. It is organized into 12 categories, each of which contains from 12 to 25 individual technologies.

The technology categories in this questionnaire are as follows:

BIOTECHNOLOGY, MEDICINE AND LIFE SCIENCES
CHEMISTRY AND CATALYSIS
COMBUSTION, PROPULSION AND ENERGY
COMMUNICATIONS, RADAR AND SIGNAL PROCESSING
COMPUTERS
DIRECTED ENERGY RELATED TECHNOLOGY
ELECTRONIC MATERIALS AND DEVICES
FLUID DYNAMICS
MACROSCOPIC MATERIALS
OPTICS AND LASERS
REMOTE SENSING, OCEANOGRAPHY AND METEOROLOGY
ROBOTICS, AUTOMATION AND MACHINE INTELLIGENCE

Please pick those three or four categories in which you feel most expert, and concentrate on answering only those.

For each category, there is an initial (colored) sheet displaying the results of the "value" and "availability" poll for the relevant specific technologies distributed to all of you in the previous poll. At the time these summary data were prepared, responses had been received from 75 experts. This initial sheet is followed by a longer list of technologies for you to rate. In addition to being asked to rate the value of each technology and its availability date, you are being asked to justify or explain those ratings by describing specific milestones or research developments that must occur to make this technology available and to give one or more specific applications. Try to avoid using generic responses such as "need more research." "Availability" presumes a successful demonstration of the technology, but precedes actual routine use or actual application to a military or commercial product, process, or system. As in the previous questionnaire, times are specified in 5-year intervals.

You are also being asked to provide specific examples of significant applications of the technology, to aid you in gauging its importance. As before, the relative importance is to be specified on the following crude scale:

0 = unimportant
1 = possibly of same importance
2 = of average importance
3 = of greater than average importance
4 = very important; outstanding value

This importance should be determined by your view of the significance of potential military or commercial applications.

APPENDIX 6

DELPHI-IDENTIFIED ETS CATEGORIZED BY TECHNICAL AREA

APPENDIX 6

DELPHI-IDENTIFIED ETS CATEGORIZED BY TECHNICAL AREA

CANDIDATE TECHNOLOGIES	Value 0	Value 1	Value 2	Value 3	Value 4	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	no data
BIOTECHNOLOGY, MEDICINE AND LIFE SCIENCES													
1. Blood surrogates for universal transfusability, competitive with natural product		1	3	16	28		13	10	9	7	4	27	5
2. Therapeutic materials incorporating neurotransmitters for improving human behavior and performance		4	9	9	13	1	3	4	5	8	11	40	3
3. Therapeutic materials for control of human immune response in treatment of diseases			3	10	32		7	14	8	9	3	30	4
4. Drugs effectively targeted against specific cell types (e.g., cancer cells) with sustained release		1	2	8	35		13	9	5	12	3	29	4
5. Development of organisms that will metabolize toxic waste products		4	8	11	21		11	11	2	4	6	30	5
6. Development of organisms that will counter the biodegradation of structures	1	5	9	13	12		6	13	5	4	7	35	5
7. Development of design rules and engineering principles for synthesis of proteins with desired properties		2	4.	12	21		6	10	9	6	4	36	4

Circle one date and one value in each box.

1. BLOOD SURROGATES FOR UNIVERSAL TRANSFUSABILITY, COMPETITIVE WITH NATURAL PRODUCT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. THERAPEUTIC MATERIALS INCORPORATING NEUROTRANSMITTERS FOR IMPROVING HUMAN BEHAVIOR AND PERFORMANCE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. THERAPEUTIC MATERIALS FOR CONTROL OF HUMAN IMMUNE RESPONSE IN TREATMENT OF DISEASES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

EMERGING TECHNOLOGIES

Circle one date and value in each box.

4. DRUGS EFFECTIVELY TARGETED AGAINST SPECIFIC CELL TYPES (E.G., CANCER CELLS) WITH SUSTAINED RELEASE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

5. DEVELOPMENT OF ORGANISMS THAT WILL METABOLIZE TOXIC WASTE PRODUCTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

6. DEVELOPMENT OF ORGANISMS THAT WILL COUNTER THE BIODEGRADATION OF STRUCTURES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box

7. DEVELOPMENT OF DESIGN RULES AND ENGINEERING PRINCIPLE FOR SYNTHESIS OF PROTEINS WITH DESIRED PROPERTIES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

8. COMPLETELY CLOSED LIFE SUPPORT SYSTEMS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

9. PROTECTIVE COMPOUNDS TO MINIMIZE PHYSIOLOGIC DAMAGE CAUSED BY RADIATION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and value in each box

10. SYSTEM FOR DETOXIFICATION OF PERSONNEL AND EQUIPMENT EXPOSED TO BIOLOGICAL AND CHEMICAL AGENTS WITHOUT HARM TO PERSONNEL

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. BIOSENSORS BASED ON NEURO-RECEPTORS FOR IMPARTING SPECIFICITY

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. USE OF BIOTECHNOLOGY (CHEMICALS AND "INTELLIGENT" BACTERIA AS AN AID TO MICROELECTRONICS PRODUCTION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

13. MULTIPURPOSE DETOXIFYING AGENT AGAINST CHEMICAL WARFARE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. "VACCINE" AGAINST CHEMICAL WARFARE AND RADIATION EFFECTS (EVEN IF ONLY SHORT-TERM)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. SALT WATER CROPS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

16. CONTROL OF BIOLOGICAL AGING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. AUTOMATIC DISCOVERY OF VACCINES, DISEASES, ETC. THROUGH COMPUTER MODELS OF LIVING MOLECULES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. COMPUTER ANALYSIS OF LARGE MOLECULES (VIRUSES, ETC.)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

19. DETECTION AND MODIFICATION OF AUTOMATIC BEHAVIOR SYNDROME

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

20. SENSORS FOR MONITORING CHANGES IN HUMAN ALERTNESS AND VIGILANCE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

21. PHARMACOLOGICAL ENHANCEMENT OF PERFORMANCE USING CIRCADIAN PHASE-RESETTING DRUGS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

22. MATHEMATICAL MODELS FOR DESIGNING BIOCOMPATIBLE DUTY-REST SCHEDULES FOR ROUND-THE-CLOCK OPERATIONS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

23. ENHANCEMENT OF ALERTNESS ON DUTY BY CIRCADIAN SCHEDULING OF NAPS AND SLEEP PERIODS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

CANDIDATE TECHNOLOGIES

CHEMISTRY AND CATALYSIS

	Value 0	1	2	3	4	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	no data
1. Physical separation of gases or liquids by means of hollow fibers or affinity chromatography	2	2	1	12	3	4	5	6	2	2		44	3
2. Use of thermite combustion reactions to make high temperature materials	1	6	3	9	2	4	15	9	1	1		44	1
3. Laser synthesis of energetic molecules		7	9	21	4	2	13	14	4		3	34	1
4. Methanol production from atmospheric CO_2 using solar energy	1	8	10	12	11		5	13	11	3	5	33	5
5. Bio-catalysis with immobilized enzymes		3	8	9	5	3	5	10	4	2	1	50	
6. Compound synthesis by solar photo-electrochemistry	2	2	14	11	2	1	7	10	7	2	2	44	2

CHEMISTRY AND CATALYSIS

Circle one date and one value in each box.

1. PHYSICAL SEPARATION OF GASES OR LIQUIDS BY MEANS OF HOLLOW FIBERS OR AFFINITY CHROMATOGRAPHY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. USE OF THERMITE COMBUSTION REACTIONS TO MAKE HIGH TEMPERATURE MATERIALS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. LASER SYNTHESIS OF ENERGETIC MOLECULES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

4. METHANOL PRODUCTION FROM ATMOSPHERIC CO_2 USING SOLAR ENERGY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. BIO-CATALYSIS WITH IMMOBILIZED ENZYMES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. COMPOUND SYNTHESIS BY SOLAR PHOTO-ELECTROCHEMISTRY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. $Al + H_2O \rightarrow H_2 + Al_2O_3$ + HEAT (RECYCLE ENERGY ECONOMY)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

8. NONINTRUSIVE MEASUREMENT TECHNIQUES FOR MULTIPHASE CHEMICAL REACTING FLOWS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

9. ENZYME CATALYSTS THAT WORK IN NON-AQUEOUS ENVIRONMENTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box.

10. MOLECULAR-LEVEL UNDERSTANDING OF HETEROGENEOUS CATALYSIS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. ACCURATE QUANTUM MECHANICAL CALCULATIONS OF THE BARRIERS TO CHEMICAL REACTIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. USE OF POLYMERS TO CONTROL SOLUTION PROPERTIES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

CANDIDATE TECHNOLOGIES

COMBUSTION, PROPULSION AND ENERGY

	Value 0	Value 1	Value 2	Value 3	Value 4	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
1. Elimination of soot formation in military engines		6	11	14	6	2	15	13	2	2	1	38	3
2. Spark-ignited diesel engines, permitting use of a wide spectrum of fuels		4	5	17	6	1	18	15	3	3	1	33	1
3. Near-adiabatic diesel engines utilizing high-temperature ceramic components (and no circulating coolant)	1	1	5	26	7		9	18	7	2	2	35	2

COMBUSTION, PROPULSION AND ENERGY

Circle one date and one value in each box.

1. ELIMINATION OF SOOT FORMATION IN MILITARY ENGINES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. SPARK-IGNITED DIESEL ENGINES, PERMITTING USE OF A WIDE SPECTRUM OF FUELS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. NEAR ADIABATIC DIESEL ENGINES UTILIZING HIGH-TEMPERATURE CERAMIC COMPONENTS (AND NO CIRCULATING COOLANT)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

4. MINIATURIZED RTG's

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. TECHNIQUES FOR PRODUCING SYNTHETIC AIRCRAFT FUELS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. ALKALI METAL/HALOGEN COMBUSTION SYSTEMS FOR CLOSED POWER PRODUCTION IN SPACE AND UNDER WATER

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. DYNAMIC FEEDBACK CONCEPTS FOR CONTROL OF COMBUSTION INSTABILITY IN AIR BREATHING AND ROCKET PROPULSION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

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____

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B. **Specific applications of this technology:**

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AVAILABILITY:
- 1985
- 1986-1990
- 1991-1995
- 1996-2000
- 2001-2005
- 2006-never

VALUE:
0 1 2 3 4

8. GAS TURBINE ENGINES CAPABLE OF BURNING AVAILABLE FUEL (LIQUID, SOLID OR GASEOUS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

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B. **Specific applications of this technology:**

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AVAILABILITY:
- 1985
- 1986-1990
- 1991-1995
- 1996-2000
- 2001-2005
- 2006-never

VALUE:
0 1 2 3 4

9. AIRCRAFT ENGINES WITH LOW INFRARED EMISSIONS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

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B. **Specific applications of this technology:**

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AVAILABILITY:
- 1985
- 1986-1990
- 1991-1995
- 1996-2000
- 2001-2005
- 2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

10. STABLE HIGH-TEMPERATURE LUBRICANTS FOR NEAR-ADIABATIC DIESEL ENGINES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3

11. HIGH-PERFORMANCE SOLID FUEL RAMJET (DUCTED SOLID ROCKET)

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3

12. LIQUID PROPELLANT GUNS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box.

13. NON-THRUST PROPULSION SYSTEM

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. GRAPHITE OXIDATION AND INHIBITION STUDIES FOR THE DEVELOPMENT OF HIGH-TEMPERATURE MATERIALS WITH EXCELLENT CHARACTERISTICS OF CORROSION-RESISTANT SURFACES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. METAL SLURRY PROPELLANTS FOR HIGH VOLUMETRIC ENERGY DENSITY AIR BREATHING FUELS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

16. LONG LIVED BATTERIES FOR SPACE APPLICATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. HIGH POWER, HIGH ENERGY DENSITY BATTERIES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. EFFICIENT, INEXPENSIVE FUEL CELLS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

19. EFFICIENT, INEXPENSIVE PHOTOVOLTAIC CELLS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

CANDIDATE TECHNOLOGIES

COMMUNICATIONS, RADAR AND SIGNAL PROCESSING

	Value 0	Value 1	Value 2	Value 3	Value 4	Availability 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	no dates
1. Development of single integrated "all-weather" visual displays for use by aircraft operator			9	23	13		17	13	7	4		29	

Circle one date and one value in each box.

1. DEVELOPMENT OF SINGLE INTEGRATED "ALL-WEATHER" VISUAL DISPLAYS FOR USE BY AIRCRAFT OPERATOR

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. OPTIMUM ADAPTIVE PROCESSING OF LIMITED AND/OR NON-ERROR-FREE DATA SETS (E.G., TIME LIMITED OUTPUTS OF REAL ARRAYS OF SENSORS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. AUTOMATIC MAPPING OF SIGNAL PROCESSING ALGORITHMS DESCRIBED IN HIGH LEVEL LANGUAGE ONTO SPECIFIC MULTIPROCESSOR ARCHITECTURE OR VLSI CONFIGURATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

4. HIGH POWER, COMPACT MM WAVE ANTENNAS WITH DISTRIBUTED SOURCES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. LOW NOISE MM WAVE RECEIVERS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. HIGH PERFORMANCE A/D CONVERSION FOR RECORDING AND SIGNAL PROCESSING (E.G., 16 BITS-5MHz; 8 BITS-500MHz)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. COHERENT SIGNAL PROCESSING SYSTEMS FOR ACTIVE/PASSIVE SPATIALLY DISPERSED SETS OF SENSORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. DISTRIBUTED AUTOMATIC CONTROL OF A COMMUNICATIONS NETWORK AND LINK PARAMETERS IN A HOSTILE ENVIRONMENT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. TWO-WAY ADDRESS SELECTABLE, FIBER OPTIC VIDEO/PHONE/DATA NETWORKS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

10. HIGH POWER SPACEBORNE ULF TRANSMITTERS FOR SUBMARINE COMMUNICATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. LOS COST, HIGH-SPEED A-D/D-A WITH BUILT-IN FILTERING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. MULTI-SIGNATURE DECOYS (INCLUDING VISUAL HOLOGRAMS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

13. ACTIVE CONTROL OF RADAR CROSS SECTIONS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. MATERIALS WITH REDUCED RADAR AND IR SIGNATURES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. ANTENNAS WITH LOW RADAR CROSS SECTIONS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

16. AIR VEHICLES WITH VERY LOW OBSERVABLE SIGNATURES THROUGH MULTI-DISCIPLINARY TECHNOLOGY INTEGRATION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. DETERMINATION OF DIELECTRIC PROPERTIES OF TARGETS FROM INVERSE SCATTERING METHODS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. ACTIVE CONTROL OF RADIATED SOUND

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

19. ACTIVE CONTROL OF REFLECTED SOUND (TARGET STRENGTH)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

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____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

20. PICO-SECOND PULSE COMPRESSION FOR HIGH POWER SPIKES AND COUNTER STEALTH

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

CANDIDATE TECHNOLOGIES

COMPUTERS

	Value 0	Value 1	Value 2	Value 3	Value 4	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	[illegible]
1. Automatic generation of software from "natural language"		6	6	20	27		10	21	14	5	8	16	1
2. Parallel processing based on cosmic cube architecture		1	10	9	22	1	20	7	4	2		33	3
3. Architecture based on neuron connectivity in mammalian brains	1	11	4	25	9		6	9	14	5	12	25	-
4. Very fast, small, inexpensive read-and-write memories		1	9	21	29	2	24	23	6	1		14	5

COMPUTERS

Circle one date and one value in each box.

1. AUTOMATIC GENERATION OF SOFTWARE FROM "NATURAL LANGUAGE"

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. PARALLEL PROCESSING BASED ON OPTICAL COMMUNICATION BETWEEN N PROCESSORS AND M MEMORIES (NOT NECESSARILY CHIP-TO-CHIP OPTICAL INTERCONNECTIONS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. PARALLEL PROCESSING BASED ON NOVEL INTERCONECT HARD WIRED (NON-OPTICAL) SCHEMES (E.G., "COSMIC CUBE" ARCHITECTURE)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

4. ARCHITECTURE BASED ON NEURON CONNECTIVITY IN MAMMALIAN BRAINS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. VERY FAST, SMALL, INEXPENSIVE READ-AND-WRITE MEMORIES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. HIGHLY PARALLEL ARCHITECTURE BASED ON SYSTOLIC CHIPS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. COMPUTER LANGUAGE WHICH IS REALLY APPROPRIATE FOR PARALLEL PROCESSING

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

8. ABILITY TO DEAL WITH LARGE MASSES OF DATA FROM MANY (10^4) SENSOR LOCATIONS IN A HIGHLY CLUTTERED NON-STATIONARY ENVIRONMENT, AS IN A DISTRIBUTED SYSTEM

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

9. METHODS OF IN-PUTTING (WITH REGULATION) POWER AND REMOVING HEAT FROM LARGE COMPUTER SYSTEMS WHICH HAVE CYCLE TIMES OF LESS THAN APPROX. 2 NANOSECONDS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and value in each box

10. SQUID SUPERCOMPUTERS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. COMPUTATIONAL METHODS USING NUMERICAL AND SYMBOLIC DATA

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. TOTALLY AUTOMATED "SILICON COMPILERS"

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

13. HIGH-SPEED COMPUTERS--PARALLEL AND ARRAY PROCESSORS IN COMPACT PORTABLE MODULES (I.E., DESK-TOP CRAYS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. MELDING OF BEST FEATURES OF DIGITAL AND ANALOG COMPUTING INCLUDING OPTICAL PROCESSING, TO GET EXTREMELY HIGH COMPUTATION RATES, WITH APPROPRIATE DYNAMIC RANGE, ON MANY PARALLEL CHANNELS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. ARRAY DETECTORS AND RADIATOR TO REPLACE MECHANICALLY MOVING DISK AND TAPE RECORDING DEVICES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

16. HIGH PERFORMANCE NUMERICAL ALGORITHMS FOR STIFF, SINGULAR, OR DISCONTINUOUS PROBLEMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

17. REALISTIC 3-D MODELS OF PHYSICAL PHENOMENA (FLUID FLOW, PROPERTIES OF MATERIALS) USING SUPERCOMPUTERS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

18. HARDWARE-SOFTWARE INTERFACES FOR COMPUTATIONAL TECHNIQUES FOR CONTROL, STABILIZATION AND IDENTIFICATION OF LARGE DISTRIBUTED PARAMETER SYSTEMS--SPECIFICALLY USE OF PARALLEL ARCHITECTURES IN THESE PROBLEMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

CANDIDATE TECHNOLOGIES

DIRECTED ENERGY RELATED TECHNOLOGY

	Value 0	Value 1	Value 2	Value 3	Value 4	Availability: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	cat
1. High-current radiofrequency quadrupole accelerators		4	3	9	2	1	4	8	2	2		57	
2. Reusable opening switches for very high power (10^{10} - 10^{12} w), high voltage (approx. MV), approx. nsec rise times		3	5	12	13	1	7	13	4	4	2	42	

DIRECTED ENERGY RELATED TECHNOLOGY

Circle one date and one value in each box.

1. HIGH CURRENT RADIOFREQUENCY QUADRUPOLE ACCELERATORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. REUSABLE OPENING SWITCHES FOR VERY HIGH POWER (10^{10}-10^{12}w), HIGH VOLTAGE (APPROX. MV), APPROX. NSEC RISE TIMES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. HIGH-CURRENT, LOW-EMITTANCE ION SOURCES FOR TRITIUM AND LITHIUM BEAMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

4. NEGATIVE ION (E.G., HYDROGEN) BEAM NEUTRALIZATION USING LASERS FOR PHOTODETACHMENT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. LIGHT-WEIGHT NON-NUCLEAR SPACE POWER SOURCES IN 5-50 MW POWER REGIME

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. LASER-GUIDED CHARGED PARTICLE BEAM PROPAGATION IN THE ATMOSPHERE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. DEW CONCEPTS USING ANTI-MATTER BEAMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. HIGH-VOLTAGE INSULATORS FOR PULSED APPLICATION IN SPACE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. COUPLED RESONATORS FOR LASER POWER SCALING TO HIGH BRIGHTNESS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

10. LASER PHASED ARRAYS FOR LASER POWER SCALING FOR HIGH BRIGHTNESS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

11. LARGE DEFORMABLE OPTICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

12. WAVEFRONT SENSORS (RETURN AND OUTGOING)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

Circle one date and one value in each box.

13. COOLED APERTURE SHARING ELEMENTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. NON LINEAR PHASE CONJUGATION TECHNIQUES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. COOLED DEFORMABLE OPTICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

16. HIGH CURRENT DENSITY, HIGH SPEED, CURRENT COLLECTORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. ADVANCED MATERIALS PER HIGHER STIFFNESS-TO-MASS, EROSION RESISTANCE AND HIGHER MAGNETIC SATURATION FLUX DENSITY FOR E.M. PROPULSION DEVICES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. VERY HIGH BANDWIDTH, AGILE LASER RADARS FOR E.M. GUN TARGETING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

19. HIGH EFFICIENCY, HIGH POWER FREE ELECTRON LASERS IN THE NEAR-IR OR VISIBLE

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

20. VERY PRECISE, SHORT TIME CONSTANT ATTITUDE CONTROL SYSTEMS FOR LARGE SPACECRAFT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

CANDIDATE TECHNOLOGIES

ELECTRONIC MATERIALS AND DEVICES

Candidate Technologies	Value 0	Value 1	Value 2	Value 3	Value 4	Availability 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
1. Synthetic nonlinear optics materials custom-designed for specific applications (e.g., optical computer elements)		1	11	27	9		19	15	8		2	27	-
2. Integrated sensors on an electronic chip for measurement of pressure, temperature, acceleration	2	[illegible]	8	29	12	5	29	17	4	2	1	14	3
3. Molecular-scale electronic circuit elements and conductors		3	6	18	27		2	11	18	7	14	21	2
4. Integrated optical sensors/digital processing elements in a single chip focal plane array		1	6	28	17		16	17	10	4		23	5
5. Synchrotron radiation source X-ray lithography		5	19	9	4	2	13	16	2	1	1	38	
6. Growth of three and four components compound semiconductors of desired (specified) characteristics		2	5	21	12	2	18	7	9	1	1	35	2

ELECTRONIC MATERIALS AND DEVICES

Circle one date and one value in each box

1. SYNTHETIC NONLINEAR OPTICS MATERIALS CUSTOM-DESIGNED FOR SPECIFIC APPLICATIONS (E.G., OPTICAL COMPUTER ELEMENTS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. INTEGRATED SENSORS ON AN ELECTRONIC CHIP FOR MEASUREMENT OF PRESSURE, TEMPERATURE, ACCELERATION

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. MOLECULAR-SCALE ELECTRONIC CIRCUIT ELEMENTS AND CONDUCTORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

4. INTEGRATED OPTICAL SENSORS/DIGITAL PROCESSING ELEMENTS IN A SINGLE CHIP FOCAL PLANE ARRAY

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. SYNCHROTRON RADIATION SOURCE X-RAY LITHOGRAPHY

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. GROWTH OF 3 AND 4 COMPONENTS COMPOUND SEMICONDUCTORS OF DESIRED (SPECIFIED) CHARACTERISTICS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

7. SEMICONDUCTOR DEVICE DEVELOPMENT UTILIZING BANDGAP ENGINEERING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. COHERENT SUBMILLIMETER WAVE SOURCE IN THE SOLID STATE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. ELECTRODEPOSITION PROCESSES TO PRODUCE MATERIALS FOR IC's EFFICIENTLY AND ECONOMICALLY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

10. 3-D LOGIC AND MEMORY CIRCUITS IN SINGLE MATERIAL

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. MACROELECTRONIC ARRAYS (E.G., FLAT PANEL DISPLAYS, ELECTRONIC TABLETS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. BULK CRYSTAL GROWTH Ga:As AND OTHER III-V's AND ALLOYS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

13. EXPLORATORY III-V HETEROJUNCTION HIGH SPEED DEVICES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. HETEROSTRUCTURE SUPERLATTICES OF LAYERED MATERIALS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. ELIMINATION OF COSMIC RAY INTERFERENCES IN MICROCHIPS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

16. SUPERCONDUCTIVE COMPUTER TECHNOLOGY (MORE GENERAL THAN JOSEPHSON, AS PREVIOUSLY PRACTICED AT IBM)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. DESIGN PRINCIPLES FOR SUBSTANTIALLY IMPROVED RELIABILITY OF ELECTRONIC SYSTEMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. THREE TERMINAL SOLID STATE DEVICES OPERATING ABOVE 100 GHz (3 MM) FOR RADARS, COMMUNICATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

19. OPTICAL READ/WRITE RECORDING DEVICES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

20. COMMERCIAL PRODUCTION FOR Ga:As AND OTHER SEMICONDUCTING MATERIALS IN SPACE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

21. INFRARED DETECTOR ARRAYS AT SEVERAL FREQUENCY BANDS ON A SINGLE CHIP WITH FAST READOUT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

22. SHOTTKY BARRIER-TYPE IR DETECTORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

23. HIGH SENSITIVITY PHOTODETECTORS UTILIZING SURFACE EXCITATION ENHANCEMENT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

24. HIGH DENSITY, TWO-DIMENSIONAL, SOLID STATE ARRAYS FOR IMAGING IN THE VISIBLE AND INFRARED

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

Circle one date and one value in each box

25. HIGH EFFICIENCY SOLAR CELLS FOR SPACE APPLICATIONS, ESPECIALLY III-V MATERIALS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

CANDIDATE TECHNOLOGIES

FLUID DYNAMICS

	Value 0	Value 1	Value 2	Value 3	Value 4	Availability: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
1. Underwater drag reduction via boundary layer control or modification		21	22	26	12	4	16	10	6	5	3	23	8

FLUID DYNAMICS

Circle one date and one value in each box.

1. UNDERWATER DRAG REDUCTION VIA BOUNDARY LAYER CONTROL OR MODIFICATION

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. UTILIZATION OF LARGE FLOW STRUCTURE FOR ULTRAMANEUVERABLE VEHICLES IN AIR AND UNDER WATER

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. ACOUSTIC AND FLOW STRUCTURE CONCEPTS TO PROMOTE FINE ATOMIZATION AND MIXING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

4. SUPERSONIC COMBUSTION FOR HIGH MACH NUMBER AIR BREATHING PROPULSION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

5. NUMERICAL SOLUTION OF FLUID EQUATIONS OF MOTION SO AS PRACTICALLY TO PREDICT FLOWS WITH LARGE VOLUMES OF TURBULENCE

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. TECHNIQUES FOR CONTROL OF SURFACES INFLOWS (CONTROL AND COMPUTATIONAL FLUID DYNAMICS)

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. HARDWARE AND SOFTWARE FOR THE COMPUTATION OF FULL 3-D VISCOUS FLUID FLOW AROUND COMPLEX FLIGHT STRUCTURE

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. GEOMETRICAL CONTROL OF TURBULENT JET MIXING FOR IMPROVED COMBUSTION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. VORTEX TRAPPING/DYNAMIC LIFT ENHANCEMENT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

10. DYNAMIC "THRUST" THROUGH ACTIVE AEROELASTIC CONTROL (AIRCRAFT DRAG REDUCTION)

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. MATERIAL TRANSPORT IN VACUUM VIA DROPLET STREAM

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. ADAPTIVE SUPERCRITICAL AIRFOIL DESIGN

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

13. OFF DESIGN PERFORMANCE OF LOW REYNOLDS NUMBER FLIGHT IN SEA SURFACE ENVIRONMENT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. LAMINAR-FLOW-CONTROL WINGED AIRCRAFT (LFC) FOR ECONOMY, RANGE, AND CONTROL INCREASE

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. ATTAINMENT OF SUPERSONIC FLIGHT WHICH IS ECONOMICALLY COMPETITIVE WITH PRESENT SUBSONIC TRANSPORTS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

CANDIDATE TECHNOLOGIES

MACROSCOPIC MATERIALS

	Value 0	Value 1	Value 2	Value 3	Value 4	Availability 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer
1. Conducting polymers for "all-plastic" batteries and lightweight electronics	3	10	25	8	1	14	15	8	5		26	7
2. High-permeability rare earth permanent magnet systems for low-rotating machinery, accelerators, etc.	3	9	25	4	7	15	11	2	2		34	4
3. Fiber-reinforced ceramics for high-strength applications at high temperatures	1	6	23	19	1	16	15	8			26	3
4. Development of fundamental understanding of materials surface preparation, including interface physics and chemistry on the atomic scale	1	9	16	25	2	12	11	15	5	1	24	5
5. Practical application of ion implantation and/or high energy laser irradiation to produce hard, wear and corrosion-resistant surfaces	1	13	23	15	6	26	8	7	1		23	4
6. Metal matrix composites for high strength-to-weight	2	8	26	14	4	30	9	3	1		25	3
7. Rapid solidification processing of high-strength materials	3	14	18	8	9	18	10	4			32	2
8. High-energy laser welding of structures or structural components	5	19	18	5	18	21	3	3			28	2

MACROSCOPIC MATERIALS

Circle one date and one value in each box.

1. CONDUCTING POLYMERS FOR "ALL-PLASTIC" BATTERIES AND LIGHT-WEIGHT ELECTRONICS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. HIGH-PERMEABILITY RARE EARTH PERMANENT MAGNET SYSTEMS FOR LOW-COST ROTATING MACHINERY, ACCELERATORS, ETC.

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. FIBER-REINFORCED CERAMICS FOR HIGH-STRENGTH APPLICATIONS AT HIGH TEMPERATURES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

4. DEVELOPMENT OF FUNDAMENTAL UNDERSTANDING OF MATERIALS SURFACE PREPARATION, INCLUDING INTERFACE PHYSICS AND CHEMISTRY ON THE ATOMIC SCALE

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

5. PRACTICAL APPLICATION OF ION IMPLANTATION AND/OR HIGH ENERGY LASER IRRADIATION TO PRODUCE HARD, WEAR AND CORROSION-RESISTANT SURFACES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

6. METAL MATRIX COMPOSITES FOR HIGH STRENGTH-TO-WEIGHT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. RAPID SOLIDIFICATION PROCESSING OF HIGH STRENGTH MATERIALS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

8. HIGH-ENERGY LASER WELDING OF STRUCTURE OR STRUCTURAL COMPONENTS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

9. NOVEL METHODS OF PREPARATION OF LARGE SINGLE OR POLYCRYSTALLINE MATERIALS, USUALLY PREPARED AS CERAMICS, SUCH AS SiC, AlN, ETC.

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box.

10. MANUFACTURABLE SUPERCONDUCTORS WITH TRANSITION TEMPERATURES GREATER THAN 30-40K

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. BONDING OF SURFACES BY HIGH ENERGY AND CHEMICAL ALTERATION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. PRACTICE OF ATTAINMENT OF HIGH TEMPERATURE CERAMICS THAT ARE TOUGH, DURABLE AND IMPACT RESISTANT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

13. TAILORING OF FILAMENTARY COMPOSITE STRUCTURES FOR AIRCRAFT AND OTHER VEHICLES TO AVOID INSTABILITIES (DYNAMIC) AND IMPROVE RESPONSE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. MECHANICS AND MATERIALS FOR WEAR RESISTANCE UNDER CRYOGENIC CONDITIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. LIGHTWEIGHT (DENSITY <2 G/CM^3) COMPOSITE MATERIALS FOR SPACE APPLICATION--RADIATION, VACUUM RESISTANT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

16. INORGANIC POLYMER SYSTEMS FOR HIGH TEMPERATURE STRUCTURAL APPLICATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

17. OXIDATION RESISTANT LIGHTWEIGHT COMPOSITES FOR PERFORMANCE ABOVE 3000° F

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

18. VERY HIGH TEMPERATURE, LOW-LOSS DIELECTRIC WINDOW MATERIALS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box.

19. SURFACE COATING NON-STICKING FOR WATER AND ICE TO PREVENT FOGGING AND MAKE DE-ICING UNNECESSARY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

20. CHEMICAL APPROACHES TO FORMATION OF HIGH PURITY, CRACK RESISTANT CERAMICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

21. MINERAL CARRIERS FOR NUCLEAR WASTE ELEMENTS (Zn-Gd) THAT ARE IMPERVIOUS TO LONG-TERM RADIATION EFFECTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

22. ELECTRODEPOSITION PROCESSES ENABLING THE PRODUCTION OF REFRACTORY METAL COATING AT ROOM TEMPERATURES IN AQUEOUS SOLUTIONS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

23. FUNDAMENTAL UNDERSTANDING OF THE ROLE OF ALLOYING ELEMENTS IN PRODUCING SURFACES RESISTANT TO LOCALIZED CORROSION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

24. SPACE BASED SYSTEM FOR FABRICATION OF COMPONENTS FOR SPACE STRUCTURES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

25. APPLICATION OF CERAMICS AND ADVANCED COMPOSITES TO GUNS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

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B. Specific applications of this technology:

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AVAILABILITY:

1985

1986-1990

1991-1995

1996-2000

2001-2005

2006-never

VALUE:

0 1 2 3 4

CANDIDATE TECHNOLOGIES

OPTICS AND LASERS

	Value 0	1	2	3	4	Availability: 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	
1. Ultra low-loss fiber optics	1	2	8	22	22	6	32	8	6	1	1	20	
2. Sub-wavelength optical imaging by gradient techniques	1	2	8	9	4	1	11	8	3	1		51	
3. Optical fiber sensors for measurement of physical parameters	1	2	16	33	8	11	32	7	5	2		15	3
4. Optical fiber sensors for measurement of chemical properties	1	5	21	19	7	4	26	11	4	1	1	22	6
5. Real-time holographic interferometry through fiber optics	1	4	14	14	6	2	13	12	7		3	36	2
6. Coherent gamma-ray sources (e.g., X-ray lasers)		5	8	16	18	1	12	7	15	6	3	28	[illegible]
7. Steerable laser diode arrays at powers of approx. 1 kw/cm^2		1	3	22	1		12	6	12	6		38	[illegible]
8. Rare-gas halide excimer lasers with high efficiency and high energy output		2	7	23	6	1	16	10	7	4		37	
9. Nd: YAG lasers with average >1 kw, for manufacturing		2	23	14	3	1	24	9	5	2		33	
10. CO_2 lasers for manufacturing with power >10 kw		2	22	14	6	6	25	7	3	1		31	[illegible]

OPTICS AND LASERS

Circle one date and one value in each box.

1. ULTRA LOW-LOSS FIBER OPTICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. SUB-WAVELENGTH OPTICAL IMAGING BY GRADIENT TECHNIQUES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. OPTICAL FIBER SENSORS FOR MEASUREMENT OF PHYSICAL PARAMETERS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

4. OPTICAL FIBER SENSORS FOR MEASUREMENT OF CHEMICAL PROPERTIES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

5. REAL-TIME HOLOGRAPHIC INTERFEROMETRY THROUGH FIBER OPTICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

6. COHERENT GAMMA-RAY SOURCES (E.G., X-RAY LASERS)

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

7. STEERABLE LASER DIODE ARRAYS AT POWERS OF APPROX. 1 KW/CM^2

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. RARE-GAS HALIDE EXCIMER LASERS WITH HIGH EFFICIENCY AND HIGH ENERGY OUTPUT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. Nd: YAG LASERS WITH AVERAGE POWER GREATER THAN 1 KW, FOR MANUFACTURING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

10. CO_2 LASERS FOR MANUFACTURING WITH POWER GREATER THAN 10 KW

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

11. MID- AND FAR-INFRARED OPTICAL FIBERS OF LOW-LOSS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

12. SATELLITE LASER TECHNOLOGY FOR SATELLITE-SUBMARINE (SUBMERGED) TWO-WAY COMMUNICATIONS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

13. INEXPENSIVE AND PRECISE LARGE OPTICAL SYSTEMS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

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____

____

B. **Specific applications of this technology:**

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____

____

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

CANDIDATE TECHNOLOGIES

REMOTE SENSING, OCEANOGRAPHY AND METEOROLOGY

1. NMR imaging for investigation of structural and mechanical properties of composite materials
2. Airborne/spaceborne laser radars (eye-safe) for remote sensing of global atmospheric properties
3. Acoustic imaging for reconnaissance of the interiors of structures and nondestructive testing
4. Microwave mapping of wind speed at the sea surface from satellite radar
5. Doppler weather radar (airborne) for storm and wind tracking and warning

	Value 0	Value 1	Value 2	Value 3	Value 4	Availability 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answer	[illegible]
1.		2	20	23	7	4	30	11	4	1	1	23	[illegible]
2.		2	19	26	11	1	25	10	11	4	2	[illegible]	5
3.		2	17	30	8	10	23	11	6	2		18	5
4.		2	14	31	8	6	21	13	8	1	1	20	5
5.			17	29	9	4	36	7			1	20	7

REMOTE SENSING, OCEANOGRAPHY AND METEOROLOGY

Circle one date and one value in each box.

1. NMR IMAGING FOR INVESTIGATION OF STRUCTURAL AND MECHANICAL PROPERTIES OF COMPOSITE MATERIALS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. AIRBORNE/SPACEBORNE LASER RADARS (EYE-SAFE) FOR REMOTE SENSING OF GLOBAL ATMOSPHERIC PROPERTIES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. ACOUSTIC IMAGING FOR RECONNAISSANCE OF THE INTERIORS OF STRUCTURES AND NONDESTRUCTIVE TESTING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

4. MICROWAVE MAPPING OF WIND SPEED AT THE SEA SURFACE FROM SATELLITE RADAR

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

5. DOPPLER WEATHER RADAR (AIRBORNE) FOR STORM AND WIND TRACKING AND WARNING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

6. ACTIVE/PASSIVE MULTI-SPECTRAL SCANNERS WITH AUTOMATED TERRAIN FEATURE CLASSIFICATION

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

Circle one date and one value in each box.

7. ACOUSTIC IMAGING ARRAYS FOR ANTISUBMARINE WARFARE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. LONG-RANGE WEATHER FORECASTING

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. SENSING OF SEA STATE, SURFACE WEATHER, AND REMOTE SENSING OF UPPER ATMOSPHERE FROM LARGE UNMANNED OCEAN BUOYS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

10. SMART BUOYS FOR ENVIRONMENTAL MONITORING AND SURVEILLANCE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

11. WEATHER FORECASTING SYSTEMS THAT INCLUDE ARTIFICIAL INTELLIGENCE LINKED WITH REMOTE SENSING INSTRUMENTS TO CONTINUOUSLY UPDATE FORECASTS AND THAT LEARN FROM EXPERIENCE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

12. 4-D (SPACE AND TIME) ASSIMILATION OF REMOTELY SENSED METEOROLOGICAL DATA FOR INCORPORATION INTO PREDICTION MODELS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

13. EXPANSION OF ENVIRONMENTAL FORECASTING MODELS TO ACCEPT REAL-TIME SATELLITE DATA FOR REGULAR FORECAST VERIFICATION AND CONDITION UPDATES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

____

____

____

____

____

B. **Specific applications of this technology:**

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. USE OF FULLY COUPLED AIR-OCEAN-SEA ICE MODELS FOR PREDICTION OF LEAD FREQUENCIES, ORIENTATIONS AND ICE THICKNESS DISTRIBUTION FOR THE POLAR OCEANS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

____

____

____

____

____

B. **Specific applications of this technology:**

____

____

____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. SYSTEM FOR REMOTELY DETERMINING SEA ICE THICKNESS WITH HIGH RESOLUTION AND SMALL FOOTPRINT

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

____

____

____

____

____

B. **Specific applications of this technology:**

____

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____

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

16. TECHNIQUES FOR REMOTE SENSING (IMAGING) OF MAGNETOSPHERIC ACTIVITY

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. AUTOMATED ONBOARD SATELLITE PROCESSING OF ATMOSPHERIC AND OCEAN CHARACTERISTICS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. SATELLITE BORNE ALTIMETERS FOR TIME VARIABILITY OF OCEAN SURFACE WAVES AND CURRENTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

19. COMBINED RADAR, RADIOMETER AND LIDAR PROFILE OF ATMOSPHERIC WIND, TEMPERATURE AND HUMIDITY FOR USE IN SHORT- AND MEDIUM-TERM WEATHER FORECASTS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

20. TOMOGRAPHIC ARRAYS FOR MESOSCALE OCEAN MONITORING AND FORECASTING

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

21. WINDSAT SATELLITE BORNE CO_2 LIDAR FOR MEASURING GLOBAL WIND FIELDS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box

22. SPACEBORNE OPTICAL AND RADAR SYSTEMS FOR GLOBAL MONITORING OF CO_2 AND HYDROLOGIC CYCLES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY: 1985 / 1986-1990 / 1991-1995 / 1996-2000 / 2001-2005 / 2006-never

VALUE: 0 1 2 3 4

23. AIRCRAFT SOUNDING SYSTEM WITH FAST RESPONSE INSTRUMENTS ABOARD NEW GENERATION AIRCRAFT AND AUTOMATIC READOUT VIA RADIO. THE WEATHER SERVICE COULD GET A DETAILED VERTICAL SOUNDING OF THE ATMOSPHERE WHENEVER A TAKEOFF OR LANDING OCCURS. USEFUL FROM LAND OR SHIP (CARRIERS).

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY: 1985 / 1986-1990 / 1991-1995 / 1996-2000 / 2001-2005 / 2006-never

VALUE: 0 1 2 3 4

24. GLOBAL MEASUREMENTS OF MAGNETOSPHERIC ELECTRICAL CIRCUIT FOR BETTER PREDICTIONS OF GEOMAGNETIC STORMS AND THEIR EFFECTS ON SPACE SYSTEMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY: 1985 / 1986-1990 / 1991-1995 / 1996-2000 / 2001-2005 / 2006-never

VALUE: 0 1 2 3 4

CANDIDATE TECHNOLOGIES

ROBOTICS, AUTOMATION AND MACHINE INTELLIGENCE

	Value 0	Value 1	Value 2	Value 3	Value 4	AVAILABILITY 1985	1986-1990	1991-1995	1996-2000	2001-2005	2005-never	Prefer not to answ.	
1. Automated image recognition and classification through use of AI techniques			2	25	37	3	20	19	11	9		[illegible]	[illegible]
2. Autonomous machine vision for robot self-guidance and/or industrial inspection		1	4	24	32	1	16	23	13	5	[illegible]	[illegible]	[illegible]
3. Autonomous weapons vision with automatic target recognition	1	1	5	16	32	1	12	15	17	4	2	20	[illegible]
4. Development of a working model of optimum allocation of decisions and actions between humans and machines in a man-machine system	1	2	11	24	20		13	18	8	13	5	17	[illegible]
5. Automatic understanding of speech of a specific individual		4	13	25	18	6	23	14	6	8	2	15	[illegible]
6. Automatic understanding of speech of a general class of individuals		4	18	17	23	1	15	16	15	5	7	14	[illegible]
7. Automated chemical analysis using robotics, for laboratory or manufacturing plant	1	2	21	21	12	3	34	13	4	1	1	18	[illegible]
8. Development and demonstration of design principles for substantially improved reliability of weapons systems		2	3	19	24	1	23	13	4	1	1	27	[illegible]
9. Development of unmanned, remotely addressable underwater venicles		2	12	20	17		20	17	6	3	1	24	[illegible]
10. Unmanned fighter aircraft		4	14	15	14		9	11	14	8	1	27	[illegible]

Circle the date and value in each box

1. AUTOMATED IMAGE RECOGNITION AND CLASSIFICATION THROUGH USE OF AI TECHNIQUES

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

2. AUTONOMOUS MACHINE VISION FOR ROBOT SELF-GUIDANCE AND/OR INDUSTRIAL INSPECTION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

3. AUTONOMOUS WEAPONS VISION WITH AUTOMATIC TARGET RECOGNITION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

4. DEVELOPMENT OF A WORKING MODEL OF OPTIMUM ALLOCATION OF DECISIONS AND ACTIONS BETWEEN HUMANS AND MACHINES IN A MAN-MACHINE SYSTEM

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3

5. AUTOMATIC UNDERSTANDING OF SPEECH OF A SPECIFIC INDIVIDUAL

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

. AUTOMATIC UNDERSTANDING OF SPEECH OF A GENERAL CLASS OF INDIVIDUALS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box

7. AUTOMATED CHEMICAL ANALYSIS USING ROBOTICS, FOR LABORATORY OR MANUFACTURING PLANT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

8. DEVELOPMENT AND DEMONSTRATION OF DESIGN PRINCIPLES FOR SUBSTANTIALLY IMPROVED RELIABILITY OF WEAPONS SYSTEM

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

9. DEVELOPMENT OF UNMANNED, REMOTELY ADDRESSABLE UNDERWATER VEHICLES

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and
value in each box

10. UNMANNED FIGHTER AIRCRAFT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

11. AUTOMATED DIAGNOSTICS SYSTEMS PREDICTING THE NATURE OF FAILURES IN COMPLEX SYSTEMS SUCH AS NUCLEAR POWER PLANTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

12. UNMANNED ORBITING ROBOTIC VEHICLES FOR SPACECRAFT REPAIR AND UPGRADE

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

____

____

____

____

____

B. Specific applications of this technology:

____

____

____

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

Circle one date and one value in each box.

13. REMOTELY OPERATED UNMANNED TANK/TANK KILLER GUN SYSTEMS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

14. REMOTE COMPUTER-CONTROL OF ANIMAL BEHAVIOR--ALTERNATE TO MECHANICAL ROBOTS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

15. MANUFACTURING SYSTEMS INTEGRATION TO ENABLE FACTORY OF THE FUTURE TO BE A VIABLE CONCEPT

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and one value in each box.

16. THRESHOLD LOGIC FOR DECISION MAKING IN SITUATIONS OF INCOMPLETE INFORMATION

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

17. DECISION SUPPORT SYSTEM FOR MILITARY DECISION MAKING (E.G., FOR EFFICIENT TASK ASSIGNMENT AND EFFICIENT PROCUREMENT PROCEDURES)

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

18. CAD/CAM SYSTEMS WITH PREDICTION MODELS OF HUMAN PERFORMANCE FOR DESIGN OF HUMAN INTERFACES TO LARGE-SCALE SYSTEMS

A. **Specific milestones/research developments that must occur for this emerging technology to be realized:**

B. **Specific applications of this technology:**

AVAILABILITY:
1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:
0 1 2 3 4

Circle one date and value in each box.

19. MAN-MACHINE MUTUAL MONITORING LOOPS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

20. "MUSCLE-LIKE" MECHANICAL ACTUATORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

21. ELECTRORHEOLOGICAL FLUID ACTUATORS

A. Specific milestones/research developments that must occur for this emerging technology to be realized:

B. Specific applications of this technology:

AVAILABILITY:

1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-never

VALUE:

0 1 2 3 4

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APPENDIX 7

SELECTED RESULTS OF DELPHI SURVEY

APPENDIX 7

SELECTED RESULTS OF DELPHI SURVEY

This appendix contains information from the Delphi Survey on the following technologies (an asterisk has been placed next to the technology where no protocol was written):

A-3	E-4*	G-6	J-4
B-2*	E-5	G-7	J-5
C-3	E-6	G-10	J-6
D-2	E-7	G-12	J-7
D-12	E-8	G-13*	J-9
D-13	E-13	G-14	J-11*
D-14	E-17	G-25*	J-12
D-15	F-2*	H-4	K-3
D-16	F-5*	H-15*	L-1
D-18	F-10	I-1	L-3
D-19	F-14	I-3	L-4
E-1	G-1	I-6	L-6
E-2	G-3	J-1	
E-3	G-4	J-3	

Correlation between Delphi and Workshop estimates of availability dates.

New technologies not listed in the Delphi process.

Technologies chosen by more than one Workshop session.

Availability estimates (derived from Workshop protocols).

Matrix of Delphi technology categories and Workshop sessions.

"A," "B," and "C" technologies lists.

Matrix aggregates vs. applications.

In the following technology worksheets, the solid line refers to Round 2 and the "10s" scale; the dashed line refers to Round 3 and the "3s" scale (in parentheses).

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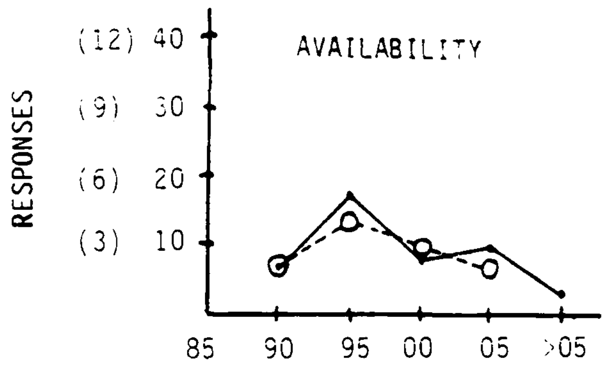
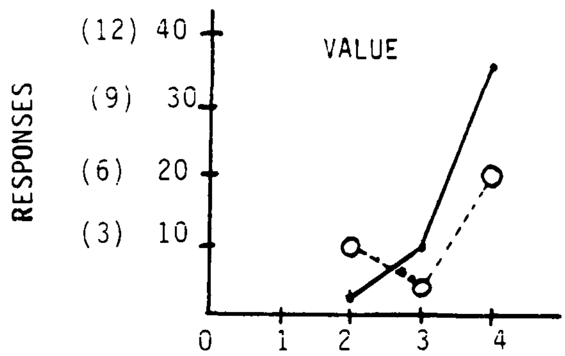
#A-3 THERAPEUTIC MATERIALS FOR CONTROL OF HUMAN IMMUNE RESPONSE IN TREATMENT OF DISEASES





NEEDED DEVELOPMENTS:

- Initial immune modulators are being produced today by RDNA techniques (e.g., IL-2 interferons); more will be isolated and characterized.
- Identification and characterization of histocompatibility of antigens and receptors.
- Demonstration of blocking or activating function of key proteins and/or peptides.
- Understanding of the role of prostaglandins.
- Define role of immune response in specific disease states where presently unclear.
- More understanding of the molecular mechanisms of immunology.
- Major limitation will be clinical studies and further understanding of immune response and regulation.
- Clinical testing and FDA approval.

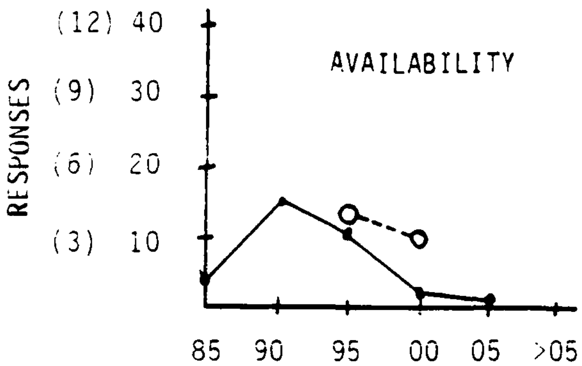
APPLICATIONS:

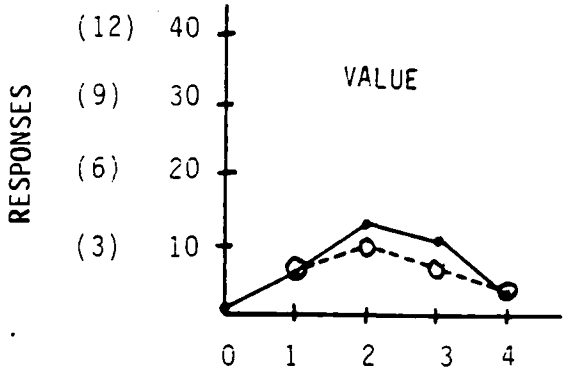
- Anti-inflammatory effects; applications in sensor technology.
- Allergy treatment.
- Transplantation; auto-immune diseases.
- Treatment of viral and immune diseases, cancers, and the infectious diseases or parasites.
- Restoration of repressed immune function.
- Inflammatory diseases, including rheumatoid arthritis, may be treatable by a type of immune response therapy.

CHOSEN BY:

Mission Support

#B-2 USE OF THERMITE COMBUSTION REACTIONS TO MAKE HIGH TEMPERATURE MATERIALS





NEEDED DEVELOPMENTS:

- In principle this is now possible, but development is necessary to determine how pure and how uniform the products are if synthesized and made into artifacts in one piece.
- Must define how high temperatures could be coupled with preparation of materials, and determine whether the thermite will contaminate the new material being prepared.
- Detailed knowledge of mechanism - particle size, ads. gases, additives for hardness.
- Control of gas contamination - pressurized reaction (in mold) - phase composition.
- Control of thermal front; scale-up.
- More mechanistic studies of reactions.
- Recognize and exploit parameters leading to:
  - o full densification of the product, and
  - o microstructural control of the resulting material.
- Understanding of solid-solid reactions and gas-solid reactions.
- Techniques to assure uniformity of materials produced from one run to another.
- This technology is known. Now work is on development only.
- Thermite combustion is only one of many methods for producing high temperatures, and it is not a particularly attractive one.
- Useful but probably too inconvenient.
- The advantages for this are difficult to see - decent temperature control could be a problem.

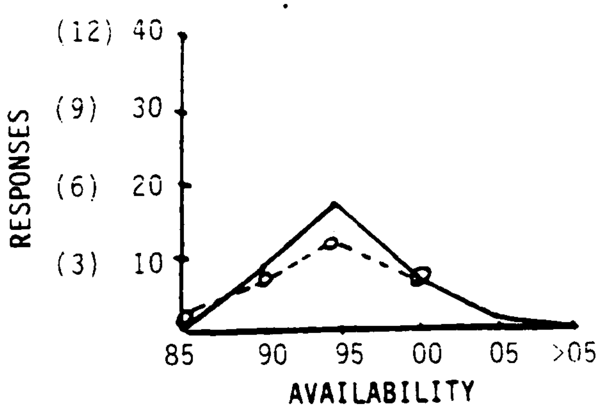
APPLICATIONS:

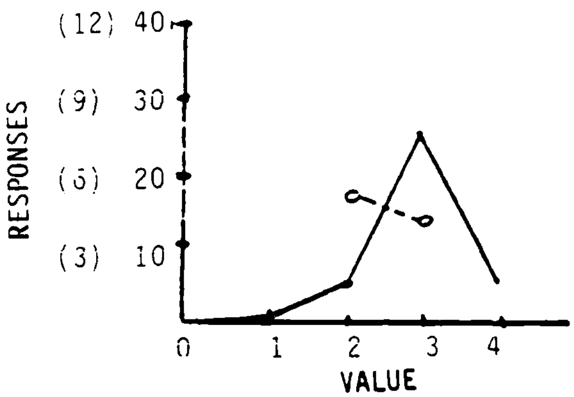
- Synthesis of TiC, TiB_2 mainly (currently) - if the above research goals are met - it will be possible to synthesize high temperature materials to near net shape.
- Tank armor, wear resistant components; high purity high temperature powders; tank treads; body armor.
- Simplified fabrication of dense refractory shapes of Darides, silicides, etc.
- New refractory alloys and ceramics.
- Inexpensive high temperature materials could have wide military and commercial use.

CHOSEN BY:

--

#C-3 NEAR-ADIABATIC DIESEL ENGINES UTILIZING HIGH-TEMEPERATURE CERAMIC COMPONENTS (AND NO CIRCULATING COOLANT)





NEEDED DEVELOPMENTS:

- NDE criteria and methods; surface flaw control; near net shape fabrication.
- Durable high temperature ceramics.
- Extensive heat transfer analysis and related component testing.
- Bonding agents for ceramics; and determination of thermal properties.
- Reduction in thermal stresses.

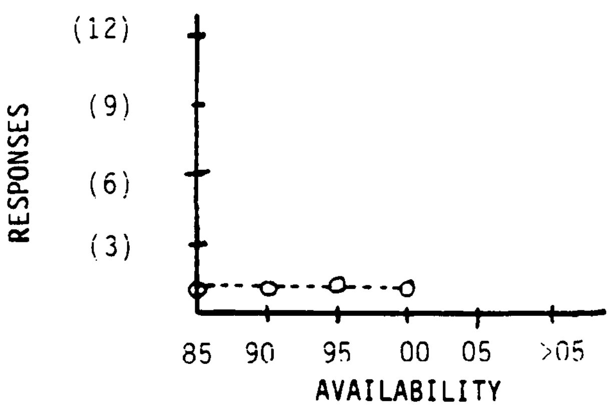
APPLICATIONS:

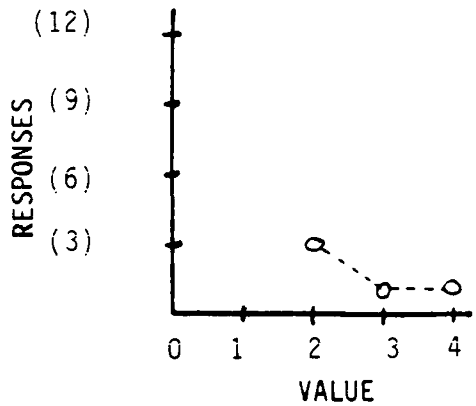
- Automotive, truck and marine engines.
- Combustion in general.

CHOSEN BY:

Mobility

#D-2 OPTIMUM ADAPTIVE PROCESSING OF LIMITED AND/OR NON-ERROR-FREE DATA SETS (E.G. TIME LIMITED OUTPUTS OF REAL ARRAYS OF SENSORS)





NEEDED DEVELOPMENTS:

- Data processing algorithms.
- Some algorithms have been developed and shown in the laboratory, and the general analytical framework is established.
- Needed: operational demonstrations (signal and noise characterization, algorithms, tailoring for real-time performance/computational requirements), development of more powerful algorithm (more sensors, decision making).
- Understanding of environmental conditions to which adaptation is required.
- Optimization algorithms for each such variable.
- Improved software and faster hardware.
- Improved A/D conversions.

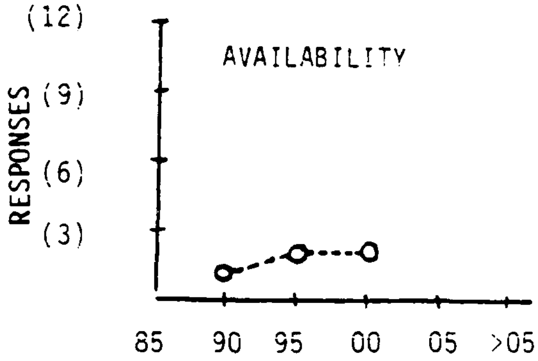
APPLICATIONS:

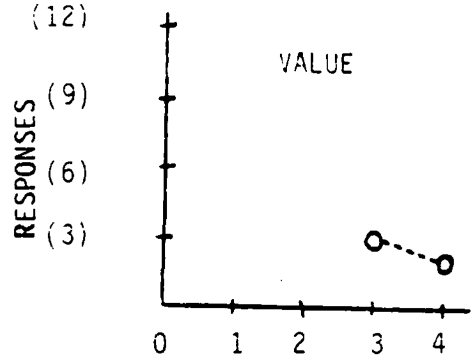
- Sensor signal processing; weather forecasting.
- Time series analysis. Coding/decoding. Imaging.
- Target detection/localization/classification.
- Terrain recongition radars.
- Optimum would also apply to specific applications and the physically constrained versus statistical characteristics of signals to be processed (e.g., diurnal temperature or thermal radiance patterns from background).
- Image enhancement.
- Processing of data from spatially distributed sensors subject to environmental and physical disruption - e.g., monitoring for intrusion.
- Null-steering antennas, speech recongition, etc.

CHOSEN BY:

Manufacturing and S&S/EW

#D-12 MULTI-SIGNATURE DECOYS (INCLUDING VISUAL HOLOGRAMS)





NEEDED DEVELOPMENTS:

- Need target/aircraft-like decoys, so that thermal images cannot be separated by algorithms.
- Design procedures for decoys to reflect RF energy in a specific manner.
- Some inventions (e.g., effective simulation of SAM's).

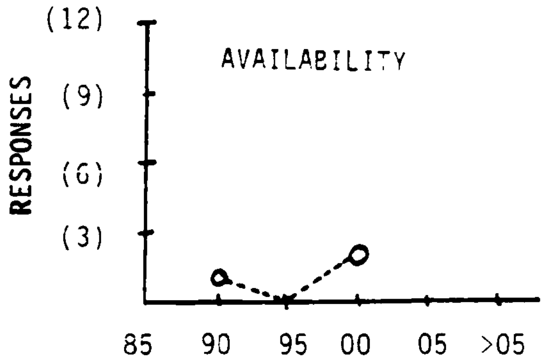
APPLICATIONS:

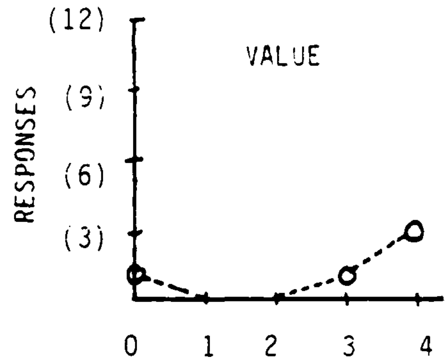
- Many applications to tactical warfare.
- Target making.
- Infrared search and track.

CHOSEN BY:

- S&S/EW

#D-13 ACTIVE CONTROL OF RADAR CROSS SECTIONS





NEEDED DEVELOPMENTS:

- RCS can be decreased somewhat now and increased greatly with little effort. This could be a controlled activity.
- Specific objectives are classified. If and when the technology is realized, it becomes absolutely essential that operational systems are fail-safe; inadvertent loss of signature control must not occur.

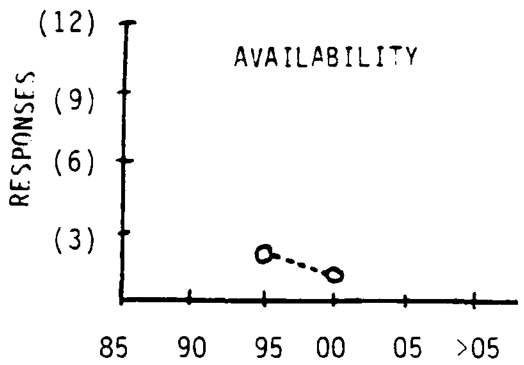
APPLICATIONS:

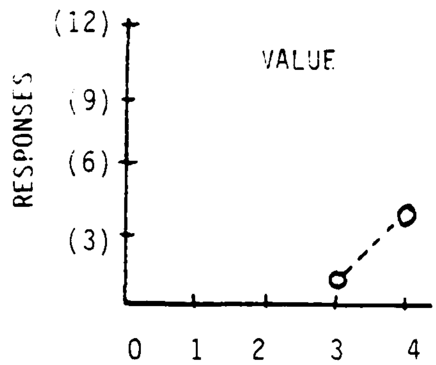
- Countermeasures to platform detectability classification and targeting.
- Counter-countermeasures in ABM.
- Make large reentry bodies look small and small decoys look large, or change size as a countermeasure.

CHOSEN BY:

- S&S/EW

#D-14 MATERIALS WITH REDUCED RADAR AND IR SIGNATURES





NEEDED DEVELOPMENTS:

- Structural and/or composite materials with ferrite properties.
- IR absorbing composite or ceramic structures and/or coating.
- Materials and shapes need to be researched and developed.
- Specific objectives are classified. If and when the technology is realized, material producibility, quality control, and operational durability become essential issues.

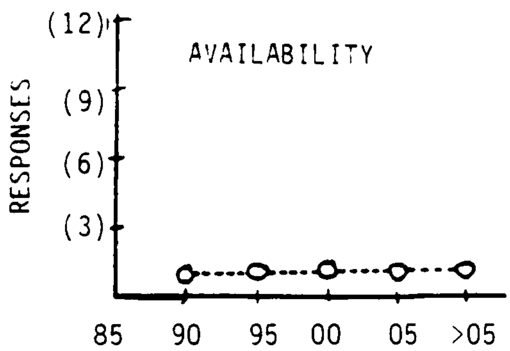
APPLICATIONS:

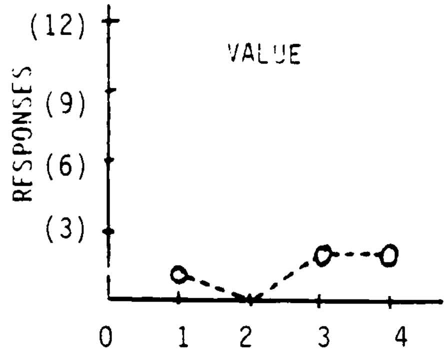
- Platform survivability enhancement via reduced signature.
- To penetrate defenses.
- Stealth.

CHOSEN BY:

- Mobility and S&S/EW

#D-15 ANTENNAS WITH LOW RADAR CROSS SECTIONS





NEEDED DEVELOPMENTS:

- This is a worthwhile but difficult topic. It seems unlikely that antenna designs could hold antenna gain constant and make huge cuts in antenna RCS.
- Capability for maintaining desired antenna beam pattern in selected directions while putting antenna "nulls" in undesired receiving directions.
- Conformal antennas.
- They can be actively changed from low RCS to efficient antennas, but they probably cannot be both simultaneously.
- Specific objectives are classified. Operational considerations will force trade-offs between antenna radar cross section and overall system performance.

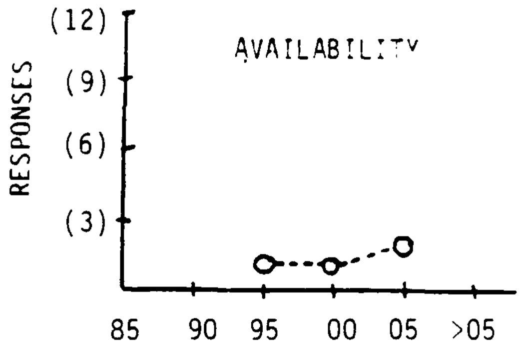
APPLICATIONS:

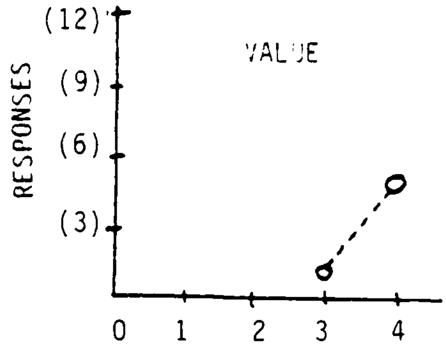
- Enhanced platform survivability while maintaining operational capability.
- Stealth aircraft.
- Reduced detectability of transmitters and receivers.

CHOSEN BY:

- S&S/EW

#D-16 AIR VEHICLES WITH VERY LOW OBSERVABLE SIGNATURES THROUGH MULTIDISICPLINARY TECHNOLOGY INTEGRATION





NEEDED DEVELOPMENTS:

- Lightweight, low drag, low RCS materials would be needed in conjunction with clearer shaped designs.
- Specific objectives and their interrelationships are classified.

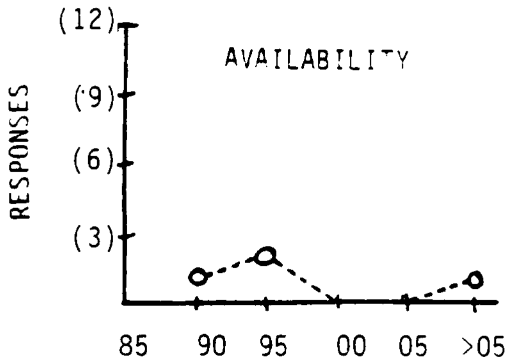
APPLICATIONS:

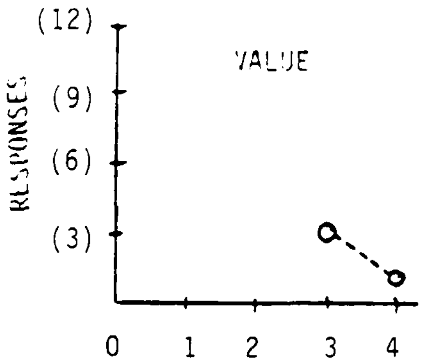
- Aircraft and missile survivability and effectiveness.
- Aircraft difficult to detect by radar.

CHOSEN BY:

- S&S/EW

#D-18 ACTIVE CONTROL OF RADIATED SOUND





NEEDED DEVELOPMENTS:

- Vibration frequency and mode shape control of large structures.
- Need improved transducers, capable of supporting heavy mechanical loads (e.g., machines) which are also capable of driving them acoustically. Also need multi-input control circuits.
- Real-time phase control of large numbered arrays.

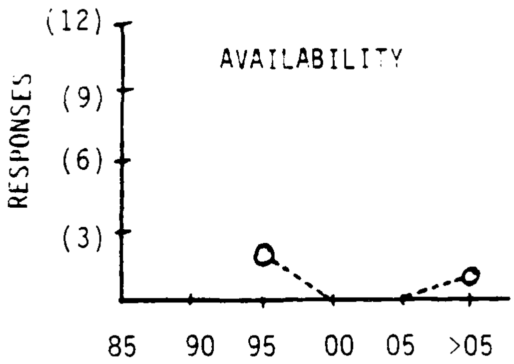
APPLICATIONS:

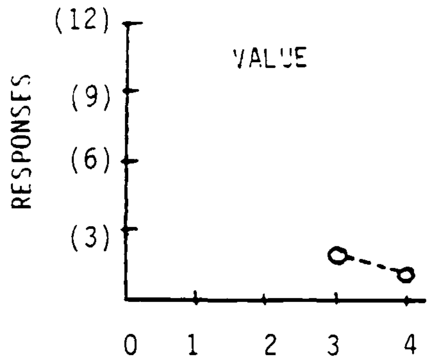
- Decoys and deception.
- Reduced underwater acoustic radiated levels from submarines; improved habitability aboard ship.
- Control sound levels emitted from submarine structure.

CHOSEN BY:

- Mobility and S&S/EW

#D-19 ACTIVE CONTROL OF REFLECTED SOUND (TARGET STRENGTH)





NEEDED DEVELOPMENTS:

- In all active-control-of-reflection problems the target has no way of monitoring the performance of whatever it does. Without this kind of feedback, and with many uncertain variables in an operational environment, these problems look very difficult, if not impossible.
- Controllable shape changes of body being interrogated.
- Adaptive control of body shape to adjust target strength in direction of receiver.
- Develop feedback/transducer compensation elements which will provide broadband cancellation. Then extend this to curved surfaces and to non-rigid backing structures. Finally, demonstrate the technology on realistic target shapes/structures.

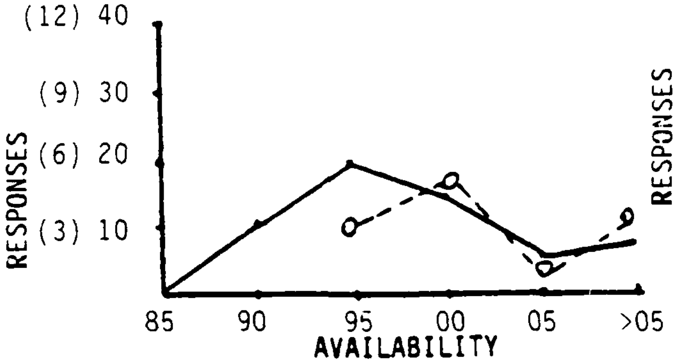
APPLICATIONS:

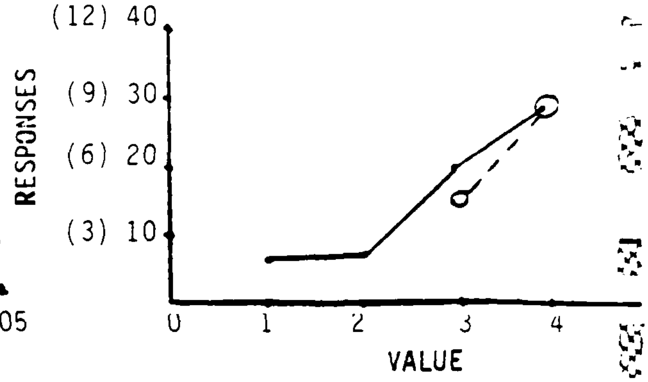
- Reduction of submarine target strength at lower frequencies (from search sonar frequencies down).
- Reduced ability to actively monitor submarines.
- Sonic stealth.

CHOSEN BY:

- Mobility and S&S/EW

#E-1 AUTOMATIC GENERATION OF SOFTWARE FROM "NATURAL LANGUAGE"





NEEDED DEVELOPMENTS:

- Need a compiler with sufficient vocabulary to translate from "natural language" context.
  1. Will evolve gradually with no specific "breakthrough" date.
  2. Substantial increases in computing power for each "user".
  3. Realization that large investments of effort must be made for each application area covered; there is no general solution to the problem.
- Robust parser for technical text (e.g., the instruction manual for a good-sized data processing system).
- "Natural language" must become a "flexible" formal language.
- Precise formulation of the software design process and study of its automation.
- Project "Gibbs" at Cornell deals with the most important ideas in this area (K. Wilson), and should be carefully watched.

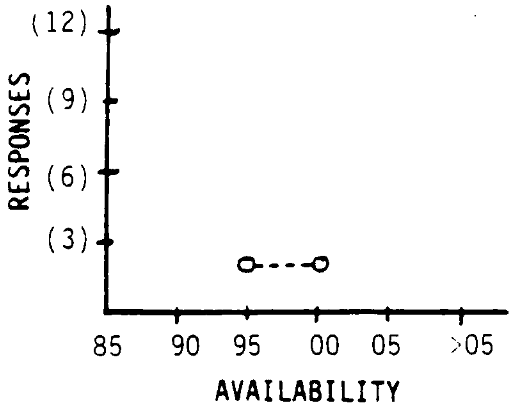
APPLICATIONS:

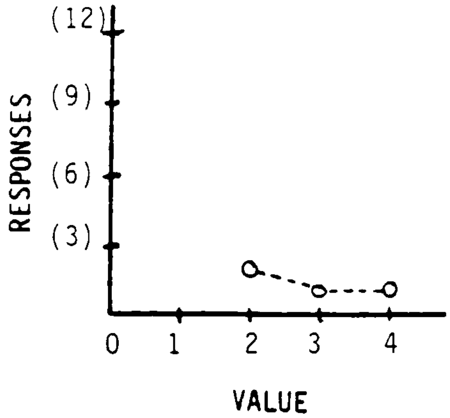
- Greatly facilitated software development.
- Field development of applications programs.
- All areas of C^3.
- Weapons development and manufacture.
- Automation of software generators has so many uses that it is hard to think of any specific application that would not fit.

CHOSEN BY:

Manufacturing and C^3

#E-2 PARALLEL PROCESSING BASED ON OPTICAL COMMUNICATION BETWEEN N PROCESSORS AND M MEMORIES (NOT NECESSARILY CHIP-TO-CHIP OPTICAL INTERCONNECTIONS)





NEEDED DEVELOPMENTS:

- Need appropriate (e.g., small, inexpensive, low power drain, very broad bandwidth) optical-electrical and electrical-optical transducers; also, control logic.
- Very wide band multiplexing ~100:1.
- Fast switch design for such communications lines.
- Must solve problems of connection and lock-up, as well as architectural and organizational problems.
- Mechanically sound optical interconnections.
- Probably N, M $\rightarrow \infty$; need probabilistic (stochastic) approaches.
- The most significant problems are mathematical.
- Efficient algorithm for utilization of such a system.
- Language design.

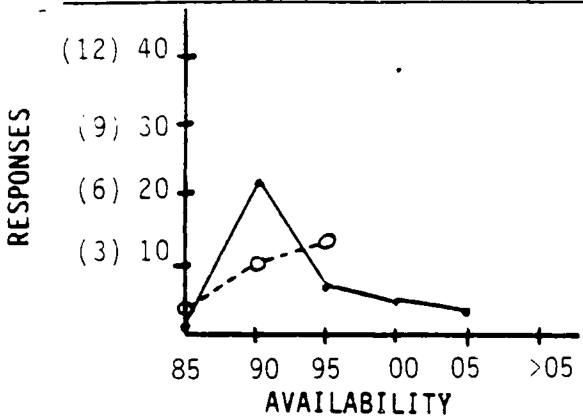
APPLICATIONS:

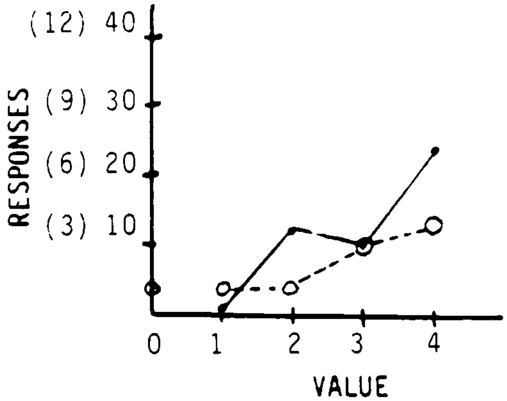
- Reduction of copper and transistors in module interconnects.
- Real-time processing and computation.
- Military will finally get the computational power it needs.
- Fast image processing; pattern recognition.
- Large-scale scientific computations, especially those in aerospace and defense.
- Faster processors.

CHOSEN BY:

C^3

#E-3 PARALLEL PROCESSING BASED ON NOVEL INTERCONNECT HARD WIRED (NON-OPTICAL) SCHEMES (E.G., "COSMIC CUBE" ARCHITECTURE)





NEEDED DEVELOPMENTS:

- Efficient algorithm design for the utilization of such systems language design.
- Compiler development and communication optimization protocols.
- Language to express incurrency, faster-than-sequential methods for communicating with processors, memory contention avoidance schemes, etc.,
- This technology is here now, and by itself means very little. The semi-automatic use of complex architecture is the next goal; it will make things practical and should occur by 1990. The automatic use of parallel processors is the longer term goal, approximately 1995.
- Solution of general problem decomposition.
- Improved allocation schemes.
- Rapid synchronization of all CPU's.
- Large I/O capability from distributed memory sites.
- Communication times between CPU's lowered.
- Problem is a mathematical one. The "cosmic cube" will likely have a very large number of vertices and stochastic interconnections.
- Need high order language control of machine.
- (This is essentially the same problem (in the long run) as D-3: Automatic mapping signal processing algorithms described in high level language onto specific multiprocessor architecture or VLSI configuration.)

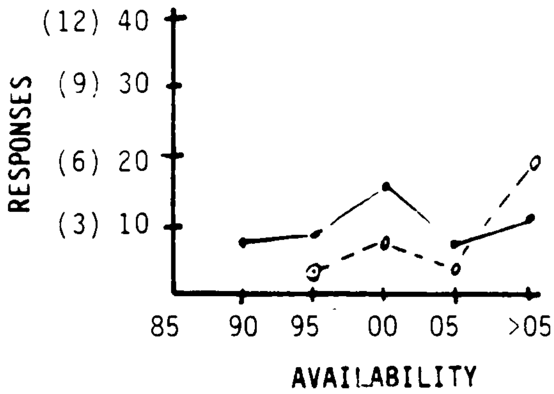
APPLICATIONS:

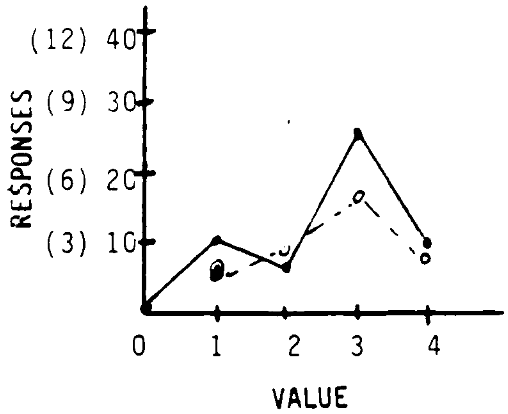
- Pattern recognition and signal processing.
- Real-time processing and computation; would finally provide needed computational power for military needs.
- Special purpose scientific processing.
- Image processing.
- Weather prediction, nuclear research, etc.
- Any application requiring huge computational resources.
- Faster and/or larger computations, more accurate simulations and modeling.
- Fast processing of complex problems.

CHOSEN BY:

C^3

#E-4 ARCHITECTURE BASED ON NEURON CONNECTIVITY IN MAMMALIAN BRAINS





NEEDED DEVELOPMENTS:

- Develop understanding of neuron connectivity and formation process, and thought process.
- Elucidate details of neural pathways, memory storage, and retrieval mechanisms.
- Detailed understanding of neural nets.
- Implementation of numerous connections.
- Understanding of "computing process" of such "systems"; algorithm design for such systems--input/output problems; development of the design and production process.
- Flexible optical interconnect and control technology.
- Cascadable systems.
- Self organizing programming.
- Submicron design rules for long IC's, compact electronic circuit analogs of synapses.
- It is unlikely that this will ever yield an efficient use of technology.
- This is not a worthwhile project; a few people should continue looking at it, but it will probably not produce anything useful in the next 25 years.

APPLICATIONS:

- Efficient approximate solution of computationally (NP) hard problems.
- Expert systems, smart weapons.
- Flexible database query systems.
- Database search AI processing.
- AI type pattern recognition problems, linear programming.
- Extremely complex architectures.

CHOSEN BY:

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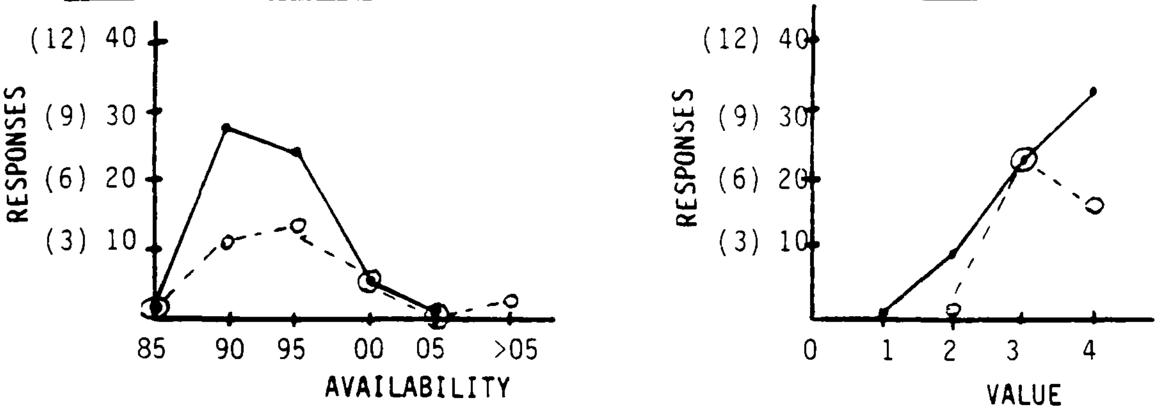
#E-5 VERY FAST, SMALL, INEXPENSIVE READ AND WRITE MEMORIES



NEEDED DEVELOPMENTS:

- III-IV compounds or silicon substrates or submicron CROS.
- Low cost requirement means self tracking readout/readin in three dimensions; all other features are here today.
- Bubble-type memories concept must be proven.
- Most signficant issues concern design and production.
- Development of faster gate technology.
- A maturing technology. The problem is making it inexpensive. High yield problems at the submicron level are here. Research is needed in artificially structural materials.
- This is an evolving process; the market place seems to be progressing naturally.
- These are getting better all the time.

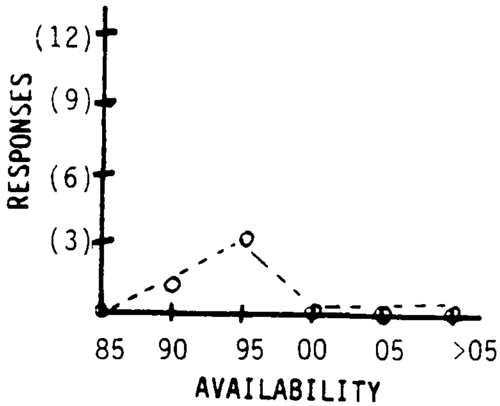
APPLICATIONS:

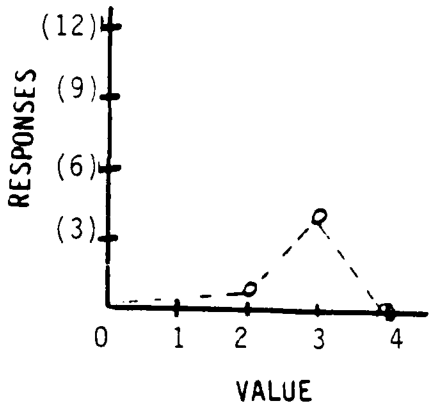
- Each increase in availability permits greater capture of sophisticated target/background discrimination algorithms in intelligent sensors, e.g., monitors.
- Replace tape as mass-storage.
- Eliminate mechanical-based storage technology.
- Distributed memory systems.
- These will be the "guts" of many devices that will appear everywhere. They will also make things economically feasible.
- Artificial intelligence.
- High speed computers.
- General purpose and specific purpose computers.
- Pocket carried cards for automatic "instant" banking, etc.

CHOSEN BY:

Manufacturing

#E-6 HIGHLY PARALLEL ARCHITECTURE BASED ON SYSTOLIC CHIPS





NEEDED DEVELOPMENTS:

- Understanding of asynchronous networks of this type; efficient algorithms for such systems; language design.
- Algorithms for mapping algorithms onto architectures.
- Higher level languages than used now (Ada is not it).
- Continual improvement in VLSI technology.
- Understanding of distributing computer control.
- Data flow algorithm development for scheduling and for computation control.
- Problem analysis to reveal those parts of problem solutions which would benefit greatly from this type of processing.
- This area is maturing fast; the key is to have enough "appropriate" algorithms designed and implemented.

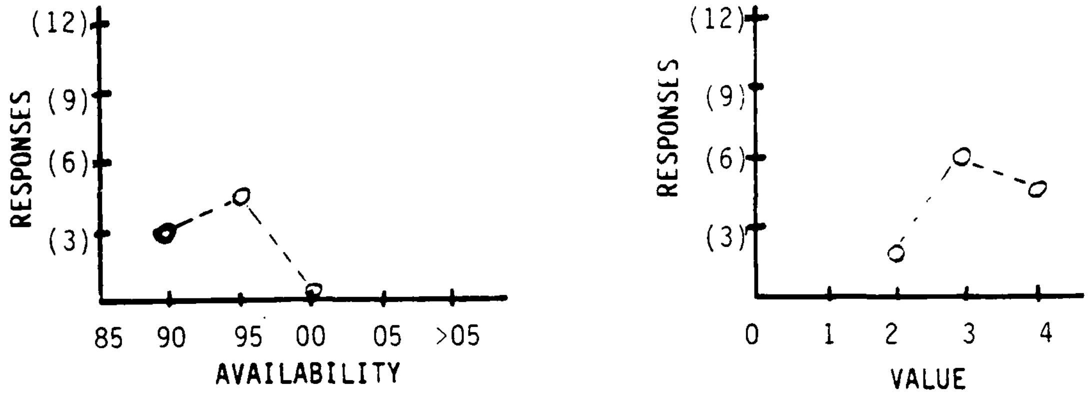
APPLICATIONS:

- Special purpose processing, particulary array, signal, or image processing.
- Large scale scientific computations.
- Faster processors.
- Reducing cost of computation and size of computers and devices.

CHOSEN BY:

Manufacturing, S&S/EW, and C^3

#E-7 COMPUTER LANGUAGE WHICH IS REALLY APPROPRIATE FOR PARALLEL PROCESSING



NEEDED DEVELOPMENTS:

- General algorithms for problem subdivision--designing of partitioning algorithms.
- Efficient models for the various types of parallelity.
- Requires new approaches to developing software.
- Development of parallel compilers capable of optimizing parallel tasking.
- Parallel processing hardware.
- Run-time experiments on multiple processor computers.
- Improvements in very high level language.
- The biggest problem will be getting people to agree upon one of the dozens of languages that will appear in the next decade.
- No single language would be universally appropriate/efficient. The choice of language would be dependent in the application and the specific architecture.
- This is a big problem. There are no signficant basic results to date. Watch MCC special project in this area. Key will be if a "reasonable" language is developed for "cosmic cube".
- Need algorithms for mapping algorithms onto architectures.
- Need to understand how to control distributed, heterogeneous systems better.
- Greater availability of parallel processing machines in the academic sector would permit training of students/professors in new thought patterns.
- This is possible, but there are not enough commercial applications to provide the impetus for fundamental and thorough development.

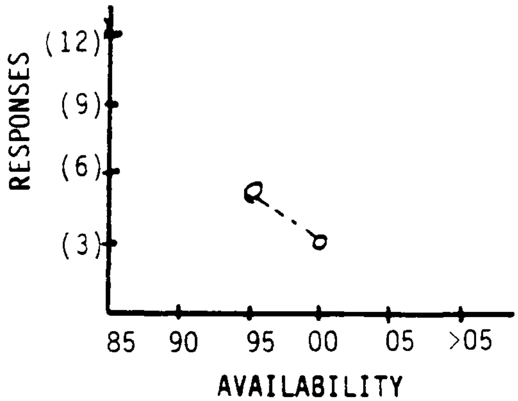
APPLICATIONS:

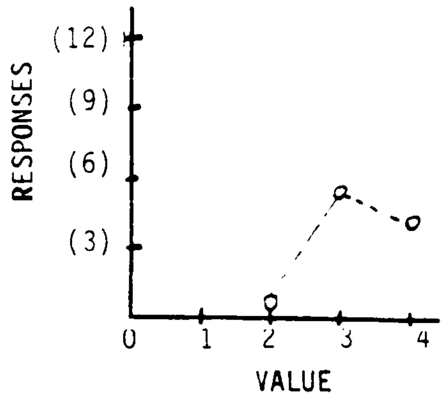
- Essential for the "standard" use of forthcoming generation of computers.
- Would open up the use of such machines to engineering/science professionals for solution of more complex problems, e.g., multidimensional radiance calculations in various emerging regimes for objects/media with irregular boundaries.
- Sensor data fusion and decision aiding.
- Required to make highly parallel architectures pay off, which in turn, has a wide range of applications.
- Facilitate programming of parallel processors.
- Sensor array data processing.
- Low cost alternative to high performance computers.
- Fast, complex computation.

CHOSEN BY:

Manufacturing, S&S/EW, and C^3

#E-8 ABILITY TO DEAL WITH LARGE MASSES OF DATA FROM MANY (10^4) SENSOR LOCATIONS IN A HIGHLY CLUTTERED NON-STATIONARY ENVIRONMENT, AS IN A DISTRIBUTED SYSTEM





NEEDED DEVELOPMENTS:

- Understanding of the process design; all of the items needed for highly parallel algorithms.
- Vector processing needs to be adapted for micro's (technology exists).
- Understanding of control of distributed, heterogeneous systems.
- More computing power, larger memories, faster communications.
- Extremely large, high speed memories.
- High speed parallel computers.
- Requires massively parallel systems.
- Control systems technology development for controlling large numbers of CPU's.
- Specify/develop integrated family of processing algorithms (e.g., intra- and inter-sensor, sensor-to-sensor handoff).
- Demonstrate expert system rules for processing information, to make interim decisions and to provide automated results for human decision.
- Demonstrate appropriate display systems.

APPLICATIONS:

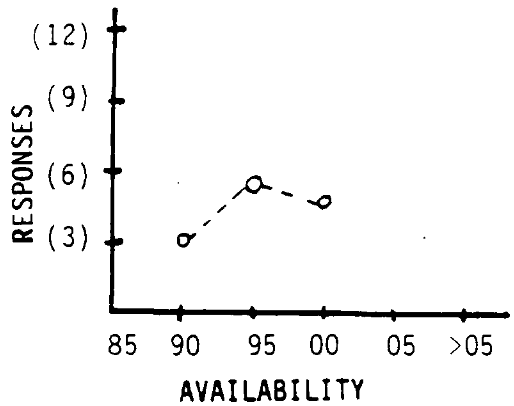
- Air and space surveillance systems (radar, IR, etc.)
- Weapon control.
- Large area distributed undersea surveillance.
- Strategic defense initiative.
- Such a sensor array might be useful in evaluating whether the environment is non-stationary. Background electromagnetic, e.g. thermal, analysis would be enhanced.
- Sensor data fusion and decision aiding.
- Control of computing "engines" themselves.

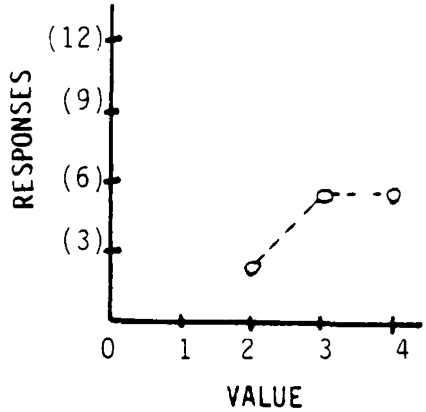
- Battlefield monitoring in real time.
- Geological explorations and meteorological computations.
- Reconnaissance and surveillance systems.

<u>CHOSEN BY</u>:

Manufacturing and C^3

#E-13 HIGH SPEED COMPUTERS--PARALLEL AND ARRAY PROCESSORS IN COMPACT PORTABLE MODULES (I.E. DESK-TOP CRAYs)





NEEDED DEVELOPMENTS:

- Requires continuing development of VLSI techniques, as well as a computer language that is really appropriate for parallel processing (#E-7).
- Much better software for parallel machines.
- Higher level, user-oriented applications languages.
- High density chip design; solution to cooling and interspace problems.
- Efficient packaging; improved cooling.
- High density of devices per chip.
- Energy dissipation system for high speed computers.
- Packaging will be a most serious "desk top" problem.
- Cost reduction of VHSIC.
- Algorithm to map algorithms onto parallel architectures.
- This technology is essentially available, in view of the new CRAY 3. What is needed now is to miniaturize all the peripherals.
- Memory management and I/O performance are the bottlenecks.
- This will be developed by industry in any case, so why should the government invest money here?
- These will be available; it's just not clear whether they will be American made.

APPLICATIONS

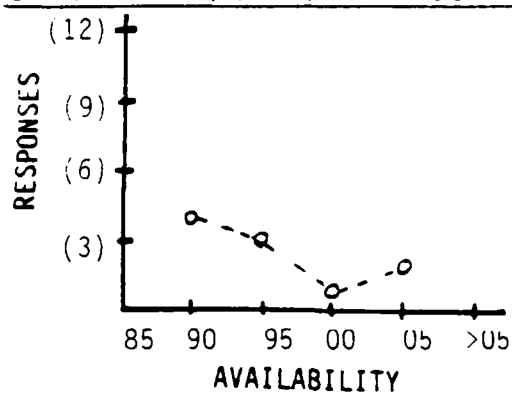
- There is always a need for more computing power. Unfortunately many cases of high power computers are on problems where computation requirements are exponential in an interesting problem parameter.
- Local moderate-level-of-complexity computations (offers convenience and flexibility, and has advantages for classified computations).
- Distributed C^3.

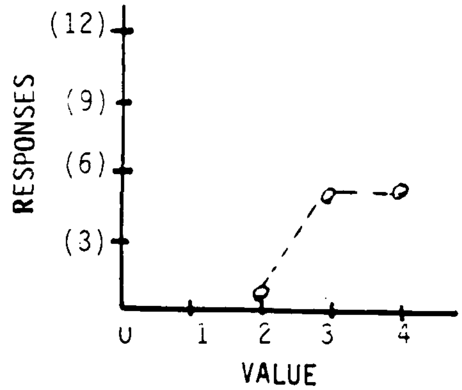
- Imbedded computers in weapons systems.
- Technical, scientific computing; SDI; smart weapons; real-time data analysis (commercial and military).
- Bring microsecond power to working scientists.
- Replace mainframe centers.
- Scientific computations in industry.
- Engineering productivity enhancement-engineering workstations.

CHOSEN BY:

Manufacturing and C^3

#E-17 REALISTIC 3-D MODELS OF PHYSICAL PHENOMENA (FLUID FLOW, PROPERTIES OF MATERIAL) USING SUPERCOMPUTERS.





NEEDED DEVELOPMENTS:

- General availability of machines in the 100-1000 MIPS range.
- Models are okay; what is needed is implementation on CRAY-2+ large memory supercomputers (256 M+) and work on obtaining results.
- Efficient adaptive methods.
- Better methods for modeling continuous processes.
- More sophisticated graphics so output can be assimilated.
- Much more computing power.
- Development of adequate computer models of observed physics; e.g., non-Newtonian fluid mechanics.
- Judiciously directed experiments to verify concepts and models.
- Trained people able to utilize new tools.
- This technology exists; what is lacking most is input data and proper physical parameterization of problems.

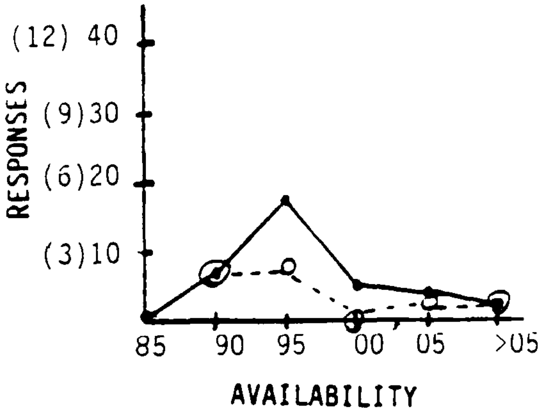
APPLICATIONS:

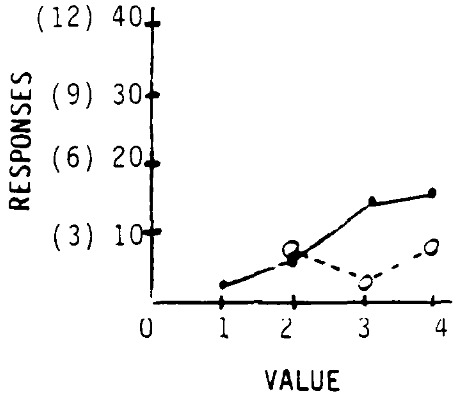
- An unlimited number of practical applications which are discipline-dependent-e.g., radiative transfer through inhomogeneous or "dirty" atmosphere, irregular scatters/absorbers.
- Extreme importance in a variety of funds, weapons design and engineering, particle beam simulation, etc.
- Aerospace and defense applications.
- Verification of less complex models.
- Fluid mechanics - kinetics crosstalk in combustion.

CHOSEN BY:

Manufacturing and S&S/EW

#F-2 REUSABLE OPENING SWITCHES FOR VERY HIGH POWER (10^{10} - 10^{12} W), HIGH VOLTAGE (~MV), ~NSEC RISE TIMES





NEEDED DEVELOPMENTS:

- Reliable high current switches that can be easily opened - perhaps laser driven.
- Obtain a better understanding of diffuse discharges (J_{peak}, J_{max}, instab., etc.).
- Do a large area exp. at V>100 KV, I~100 kA, using electron beam and optical control together.
- Repetitive demonstration of plasma erosion opening switches at required power levels.
- First stage switch to go from 100 μs to 1 μs pulse.
- Increase plasma conductivity by 1 to 2 orders of magnitude (reduction of switch losses).
- Development of very high brightness electron guns (>$A \cdot cm^{-2}$) capable of large duty cycles coupled with high reliability.
- Advances in plasma control techniques.

APPLICATIONS:

- Electromagnetic and particles accelerators - any application requiring burst of high energy, high voltage pulses.
- Electron beam accelerators for DEW kill.
- Nuclear effects simulation.
- Inductive energy storage and directed beam weapons.
- Pulse power for lasers, X-ray simulators, ion beams.
- Accelerator technology.

CHOSEN BY:

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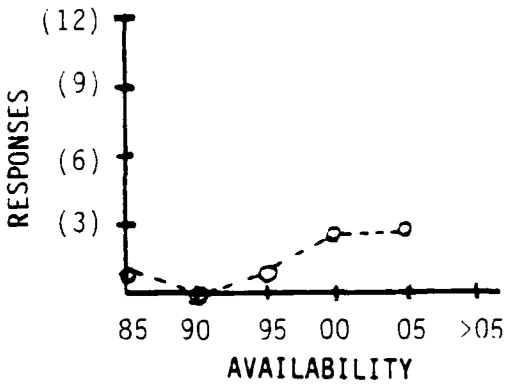
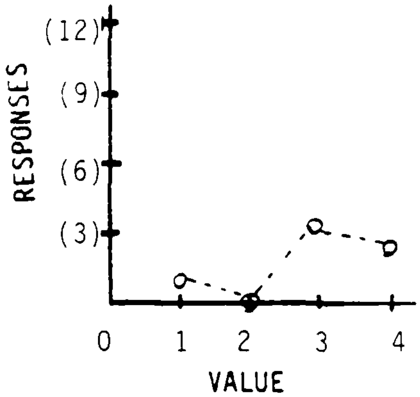
#F-5 LIGHTWEIGHT, NON-NUCLEAR SPACE POWER SOURCES IN 5-50 MW POWER REGIME





NEEDED DEVELOPMENTS:

- Thin (2 mil) 25-30% efficiency solar cells - 1990.
- NaS high energy density battery - 1995.
- High voltage generation utilization - 1995.
- In-orbit assembly of modular units -1996-2000.
- Initial operational capability - 2001-2005.
- Do an experiment at the 100 kW level and then at the 1 MW level using the *reflatable bowl principle*.
- Very high temperature ceramic engines.
- MHD generators demonstrated with high efficiency.
- Heat dissipation and weight/volume are the biggest obstacles.
- Very large scale solar cell arrays.
- Solar driven heat engines.

APPLICATIONS:

- Satellite power souces, SDI.
- Evolutionary 50 kW to 200 kW.
- Prime power for battle stations.
- Radar or lasers for surveillance or weapons.
- Laser power supply in space.

CHOSEN BY:

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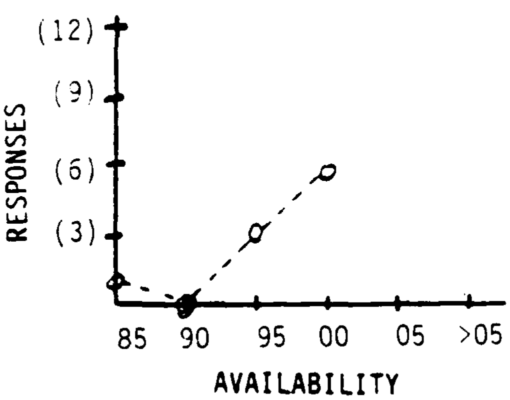
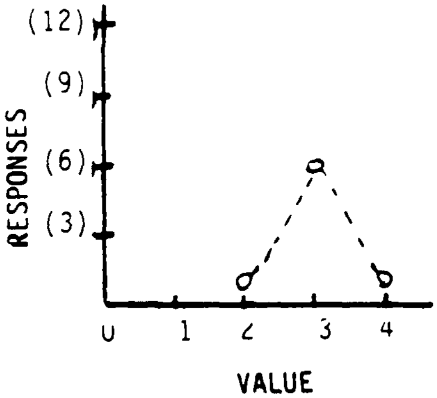
#F-10 LASER PHASED ARRAYS FOR LASER POWER SCALING FOR HIGH BRIGHTNESS





NEEDED DEVELOPMENTS:

- Computer control of phased arrays.
- Laboratory experiments extended to better fill aperture and eliminate side lobes.
- Extension to practical devices with appropriate powers.
- High power lasers must be phased reliably.
- Must demonstrate pointing and tracking by phasing.
- Development of better material control and processing.
- Measurement methods for relative phase multi-element electrooptics.
- Japanese are looking at face emitting diode-laser arrays as ultimate solution.

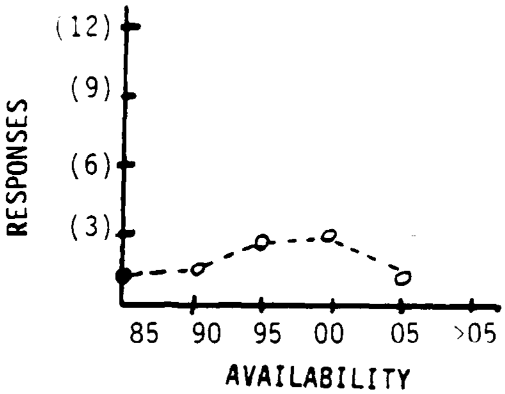
APPLICATIONS:

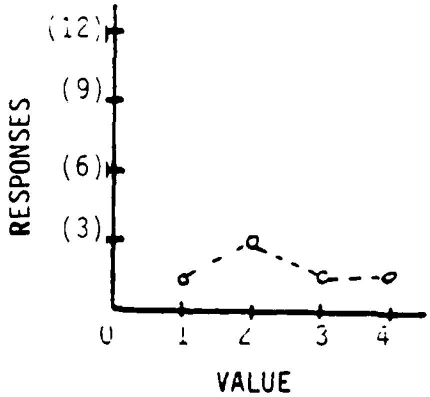
- Laser weapons and industrial devices.
- Space-based laser DEW.
- Laser radars with high gain and atmospheric compensation.
- Applications include industrial processing, parallel optical processing, remote sensing and radar.
- High brightness optical beams; SDI.

CHOSEN BY:

Directed Energy and S&S/EW

#F-14 NONLINEAR PHASE CONJUGATION TECHNIQUES





NEEDED DEVELOPMENTS:

- Must find efficient nonlinear medium. The best bet is proposed synthetic nonlinear materials based on multilayer structures.
- Large aperture operation must be demonstrated.
- High efficiency at low intensities; high fidelity amplification after conjugation.
- Extension to appropriate powers and apertures for SDI application.

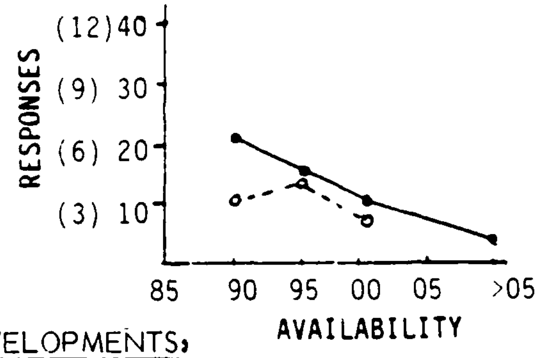
APPLICATIONS:

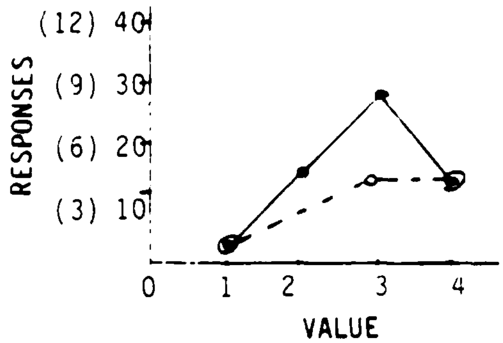
- Improve laser beam quality.
- Compensation for atmospheric turbulence.
- SDI.

CHOSEN BY:

Directed Energy

#G-1 SYNTHETIC NONLINEAR OPTICS MATERIALS CUSTOM-DESIGNED FOR SPECIFIC APPLICATIONS (E.G., OPTICAL COMPUTER ELEMENTS)





NEEDED DEVELOPMENTS:

- Search for materials and optimization. This is now underway and is a "basic" study at this point.
- Growth of films and fibers.
- Methods of depositing necessary materials in thin layers one on top of another.
- Better control of molecular beam epitaxy technology for synthesizing large crystals.
- Good new materials will ultimately be large tailored molecular non-organic epitaph. Research will therefore be on theoretical molecular calculation and synthesis.
- Development of material constants (i.e., dielectric constants); processing technology (i.e., layered structures); waveguides in layered materials.
- Low loss/low cost packages for inserting amplification into light path.
- Room temperature laser diode compatibility.
- All optical switches monolithically integrated with microelectronics.
- Optical computers in the general sense of current digital machines will never be developed. Special purpose optical processing may be more likely. Specific applications need to be demonstrated.

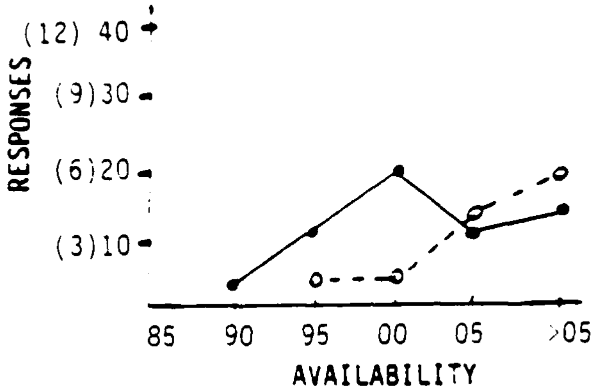
APPLICATIONS:

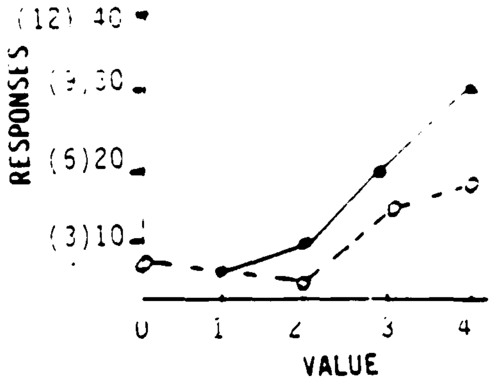
- Holography; interconnection of computers.
- Sensors for pressure, temperature, etc.
- Optical memories, computing, and signal processing.
- Local oscillators for coherent radar, remote sensing.
- Efficient harmonic generation to green, blue; efficient tunable radiation in visible and IR.
- Doubling, tripling of laser outputs to shorter wavelengths.
- This will be useful for all kinds of displays.
- Very high speed communication and data processing.
- Optical computing will most likely remain a poor prospect for the indefinite future.

CHOSEN BY:

S&S/EW and C^3

#G-3 MOLECULAR-SCALE ELECTRONIC CIRCUIT ELEMENTS AND CONNECTORS





NEEDED DEVELOPMENTS:

- Control of element composition with a low total number of atoms is required.
- Control of impurities at boundaries between materials is critical.
- Minimization of noise is also important.
- Understanding and reducing "switching" power.
- Efficient readout.
- Shot noise, quantum noise, addressing, cosmic rays, etc.
- Development of suitable molecular materials for fabrication, self-assembly techniques, analytical methods (atomic scale).
- Development of processing technology on molecular scale.
- Ultimately, complex molecules will win in this area.
- Heterojunction constructions.
- Quantum-scale elements are already in research: 80 Å wire has been prepared and studied; need lithography at 10 Å.
- Discover necessary molecular elements.
- Learn how to connect the elements together in functioning circuits.
- Learn how to get information into and out of these circuits.
- Sufficient phenomenology and some understanding of the electron physics on such length scales.
- Lithography techniques or equivalent.
- Wiring and control strategies.
- Power distribution strategies.

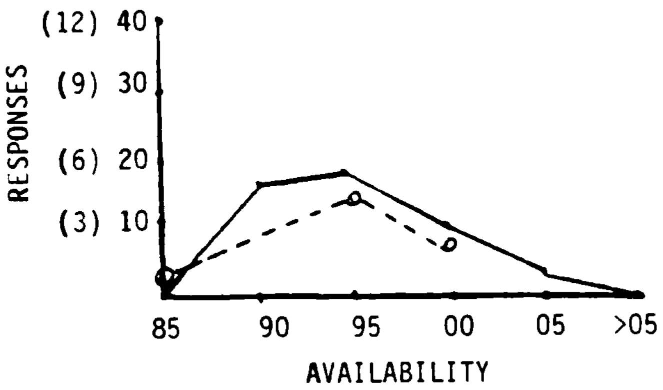
APPLICATIONS:

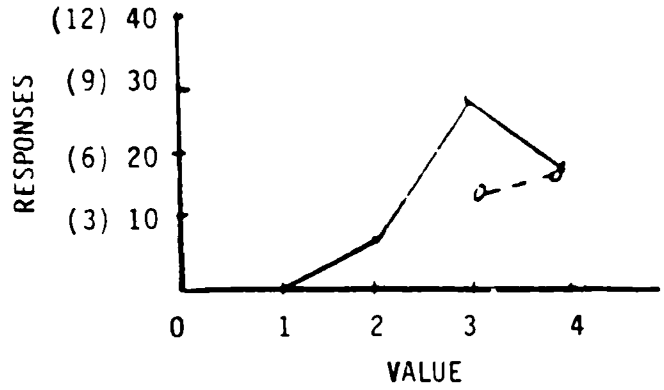
- Miniaturization of circuits.
- Because of size, a new generation of electronics will be possible.
- Quantum limited switching elements.
- Supercomputers and large scale information processing.
- Ultra-high density memories.
- Very compact circuits.
- High speed, high capacity computers.
- High speed micro processors.

CHOSEN BY:

Manufacturing and C^3

G-4 INTEGRATED OPTICAL SENSORS WITH IC PROCESSING ELEMENTS IN A SINGLE CHIP FOCAL PLANE ARRAY





NEEDED DEVELOPMENTS:

--Each wavelength range must combine sensor and electronics on the same chip. We are nearly there with existing technology in the visible and near infrared. Mid and VLW IR demand new materials development.

--Very large increase in II-V clevier yield, which is being done now. More sophistication and more complete processing will follow.

--Cooled array and simultaneous digital function.

--Some of this already exists in depth prototype arrays.

--Long distance opto-electronics, communication is being strongly driven by civilian sector.

--Knowledge of compound semiconductors on which this must be based is increasing strongly - although much more is left to do.

--Area is rich in viable concepts as well as the more spectacular concepts.

--In the military, compound semiconductor technology is being driven by needs (radiation hardness, infrared imaging, fast computers, etc.)

APPLICATIONS:

--Three-dimensional ultrafast IC's made possible by opto-electronic links in third dimension.

--Ultrafast computers made possible by optical links.

--Secure communication links from local (e.g. within single chip) to long-range (1000's of km).

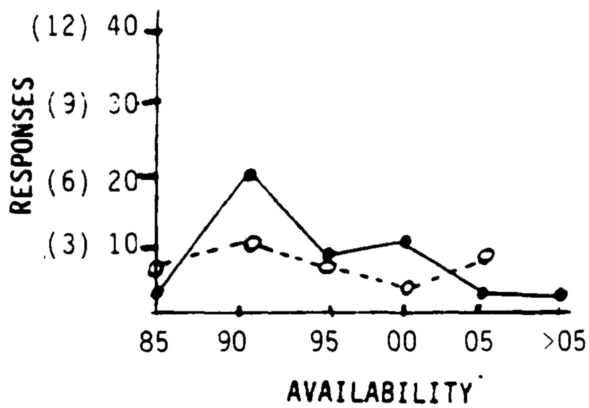
--Replacement of shipboard and aircraft control and communications links.

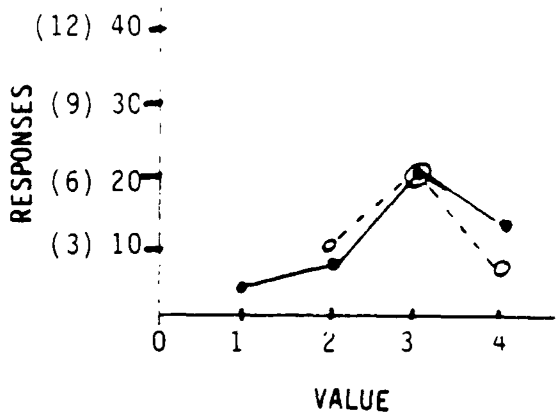
--Imaging for military ground based to satellite based.

--Sensors for robots, signal generators for computer controls, etc.

CHOSEN BY: Manufacturing, S & S/E.W., and C^3.

#G-6 GROWTH OF 3 AND 4 COMPONENTS COMPOUND SEMICONDUCTORS OF DESIRED (SPECIFIED) CHARACTERISTICS





NEEDED DEVELOPMENTS:

- New improved band structure calculations, crystal calculations of large breakthrough in low-defect crystal growth.
- Application to semiconductor characteristics of importance to specific applications.
- Suitable high volume preparation techniques such as MOCVD, allowing careful control over composition and structure, must be developed.
- Fundamental understanding of heterojunctions in context of device concepts and performance.
- Epitaxial growth as it relates to controlled thickness homogeneity, interfacial boundaries, impurity dropouts.
- Reduction in interface state densities.
- Control of processing parameters during growth.
- MBE control demonstrated by non-MBE process.
- Growth of defect-free quarternary materials.
- For 3-5 materials, already there (e.g., InOzAsP laser materials for optical communications).

(?) - Hg_{2x},Cd_xTe and related material valuable, but poor manufacturing yield.

- Reproducibility, better performance, and cost effectiveness.
- Better understanding of heteroepitaxy.
- Long lived components.

APPLICATIONS:

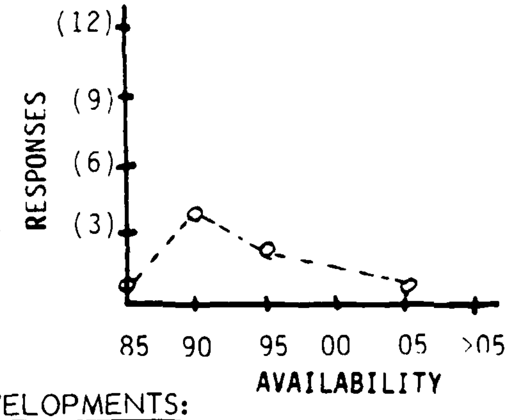
- Better lasers, detectors and transistors--smaller, faster and more efficient.
- Fast, radiation-hard IC.

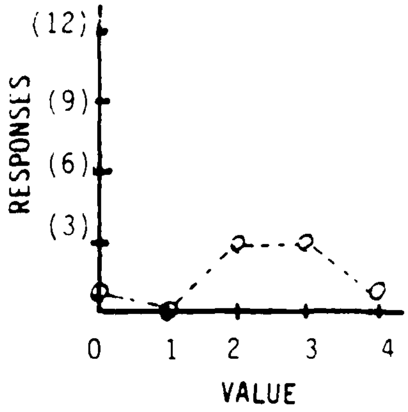
- Optical communications, integrated optical detectors and generators for optoelectronics.
- Lasers, nonlinear optical devices, modulators, switches, LED's, detectors.
- Computers, micro-millim-optical sources.
- High speed signal processing and digital circuits.
- Higher electron mobility transistor.
- Improved semiconductor devices both for higher speed circuit and for optoelectronics.
- VLSI technology.
- Long wavelength light wave communications systems.
- Essentially all semiconductor devices.
- Microwave circuits.

CHOSEN BY:

S&S/EW

#G-7 SEMICONDUCTOR DEVICE DEVELOPMENT UTILIZING BANDGAP ENGINEERING





NEEDED DEVELOPMENTS:

- Demonstration of prototype devices-e.g., lasers, high speed logic, high temperature devices.
- Ability to grow and process materials of greater complexity and chemical diversity.
- Demonstration of ZnSe p-n junction.
- In principle this is here today. HgCdTe gives capability from 1.5 to zero eV; 3-5 - 1.8 to .5 eV. Lack is in visible and UV. Material reliability and manufacturing is a problem.
- Better materials control and understanding of interfacial electronics.
- Adding 5th or 6th components or further components for bandgap engineering is *engineering in its mundane sense.*
- MBE and MOCVO machine sophistication are milestones.
- This is really the same as #G-6 (Growth of 3 and 4 components compound semiconductors of desired (specified) characteristics), only stated more generally.

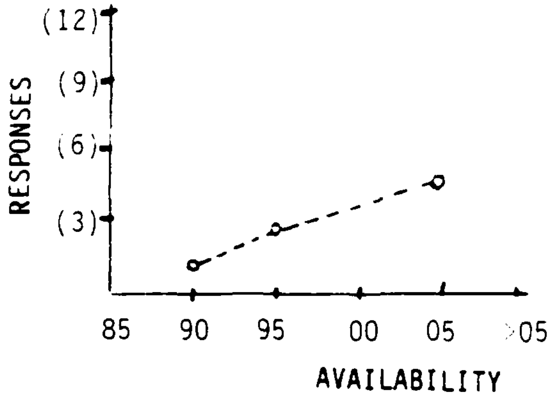
APPLICATIONS:

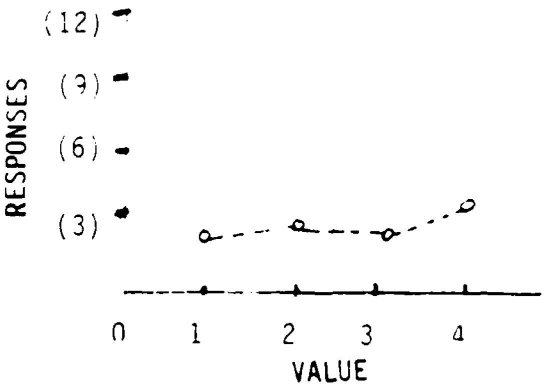
- High speed semiconductor devices.
- High performance light wave devices.
- Higher temperature operation, higher component density for larger computers.
- Detectors.
- Generation and/or detection of EM radiation.
- Focal plane detector, flat panel displays, etc.
- Blue, green, red laser sources for displays, read-write optical memories.
- Lasers, high temperature electronics, high speed logic.

CHOSEN BY:

S&S/EW

#G-10 3-D LOGIC AND MEMORY CIRCUITS IN SINGLE MATERIAL





NEEDED DEVELOPMENTS:

- Huge improvement in PI's product and yields might make it fly ultimately parallel.
- Figure out a way to make low temperature connections between various atomic layers.
- Single crystal overgrowth in multiple layers.
- Growing multi-layer devices.
- Method of burying wired devices or method of wiring to buried layers.
- Using laser processing to make third dimension.
- Vertical transport R&D.
- Processes (MBE) on a production scale.
- MBE or OMCVD able to handle insulator and interconnects as well as semiconductor materials; heat dissipation, testing and reliability.
- Cooling techniques for buried elements; heat removal technology.
- 3-D is not attractive from a thermal point of view; yields become very poor.

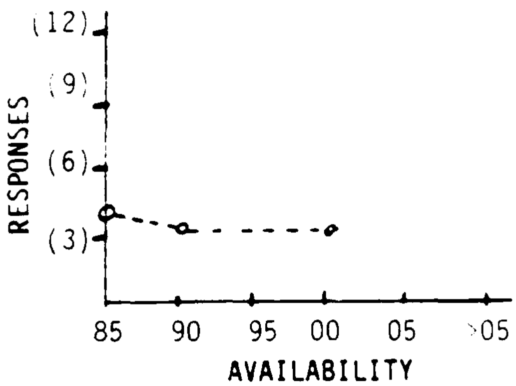
APPLICATIONS:

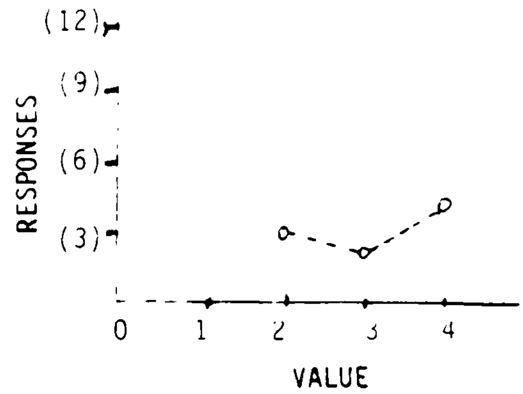
- Integrated detectors.
- Ultra small, high speed computers.
- Compact and faster circuits.
- High performance computation; advanced computers.
- Review interconnect problem in VLSI.

CHOSEN BY:

Manufacturing

#G-12 BULK CRYSTAL GROWTH Ga:As AND III-V'S AND ALLOYS





NEEDED DEVELOPMENTS:

- Investment in this technology--commitment to grow the material in the United States and not allow critical materials to be purchased from Japan.
- Low defect density, stoichiometric, high resistivity material without any doping.
- Better control of materials, reduced defect concentrations, etc.
- Research into previously unattainable regime of crystal perfection.
- Dislocation-free, large area, high resistivity wafers.
- New crystal growth techniques.
- The market will stimulate improvements as it did with silicon.
- DoD must establish market and profit motive for improved yield (productivity).

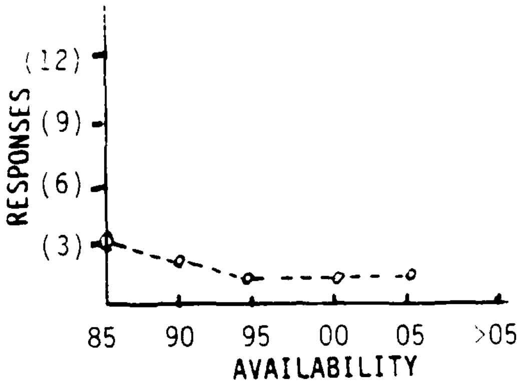
APPLICATIONS:

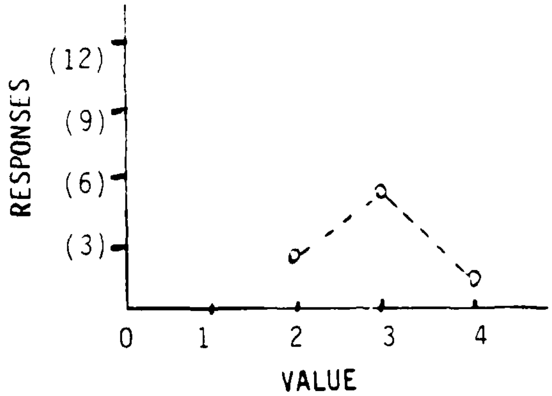
- Compound semiconductor VLSIC; MMIC.
- Microwave/millimeter wave devices; computers.
- Device and IC substrates.
- High speed circuits, optical emitters and detectors.
- All future semiconductor high speed devices.

CHOSEN BY:

Manufacturing and S&S/EW

#G-13 EXPLORATORY III-V HETEROJUNCTIO*N* HIGH SPEED DEVICES





NEEDED DEVELOPMENTS:

- Determination of factors which lead to excessive noise generated at heterojunctions.
- Exploratory devices are here today--some prototypes exist.
- Control of surface properties of the material.
- Integration of technology into systems.
- Improvement of surface morphology for MBE.
- Materials fabrication that is sufficiently defect free.
- Bipolar performance advantage.
- Better understanding and control of heterointerfaces.
- Stability of interface devices.

APPLICATIONS:

- Low pow r logic; optoelectronics.
- High speed electrons; microwaves.
- High speed processing.
- mm devices with wide bandwidth, radar.
- High speed circuits.
- High speed computers and microprocessors.

CHOSEN BY:

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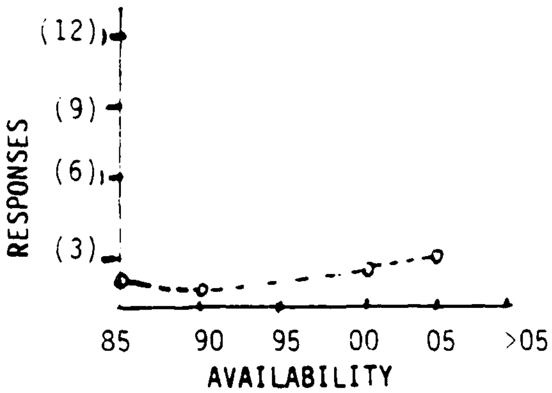
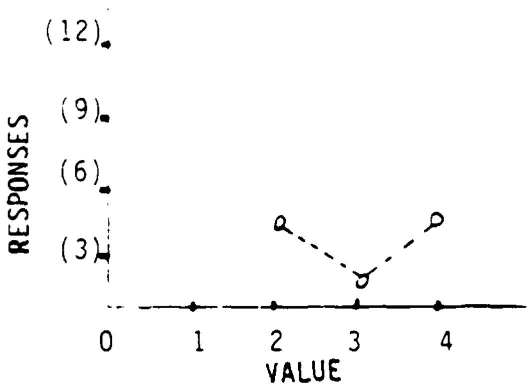
#G-14 HETEROSTRUCTURE SUPERLATTICES OF LAYERED MATERIALS





NEEDED DEVELOPMENTS:

- Production of superlattices by pulsed electrodeposition.
- Low cost (CVD?) deposition systems.
- Development of new ceramic superlattice devices.
- Sufficiently low cost reproducible materials growth techniques.
- Control of carrier concentration in various layers.
- Development of beam assisted crystal growth.
- Contact and other metalization problems must be solved.
- Development of high throughput CWD techniques.
- Processing techniques for LSI.
- Long-term stability under device operating conditions.
- This already exists.

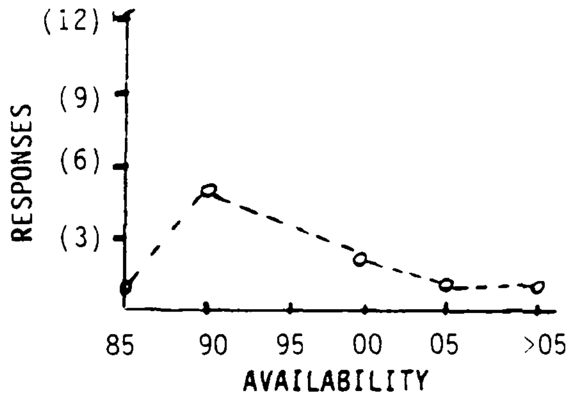
APPLICATIONS:

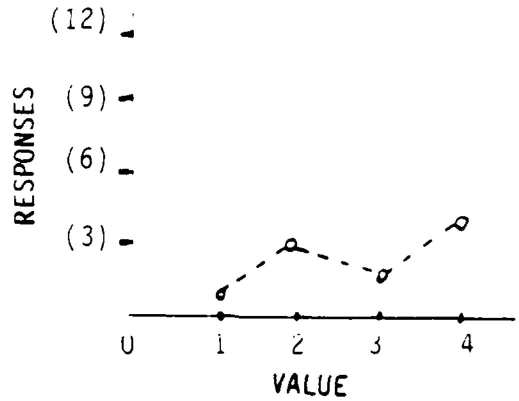
- Better layers in epi growth of materials.
- Tailored effective bandgap mobility and many other controlled features.
- Wider range of materials and material properties.
- All electronic and optoelectronic semiconductor devices.
- High speed IC's, new dielectric materials for integrated optical devices.
- May be the way to bandgap engineering of #G-6 (Growth of 3 and 4 components compound semiconductors of desired [specified] characteristics) and #G-7 (Semiconductor device development utilizing bandgap engineering).
- High strength, corrosion resistant materials.

CHOSEN BY:

Manufacturing and S&S/EW

#G-25 HIGH EFFICIENCY SOLAR CELLS FOR SPACE APPLICATIONS, ESPECIALLY III-V MATERIALS





NEEDED DEVELOPMENTS:

- Demonstrate efficiency >30%.
- 25% cells demonstrated with GaAs multijunction, solar cells with >35%.
- Tandem cells with efficiency are better than best single junction cells.
- Already close to intrinsic limit; only needs development and material perfection.
- The problems are more economical than technical. No secure market has been identified which justifies the private investment necessary to exploit this emerging technology.
- Realization of laboratory efficiencies in manufacturable, cost-effective "large" quantities.
- Repairability of large arrays in space may pose new research problems.
- Develop inexpensive electrode position processes to produce cells.
- This technology is almost here now.

APPLICATIONS:

- Power in space; solar energy.
- Space shuttle; space stations independent of other sources of energy.
- Space vehicle, concentrator.

CHOSEN BY:

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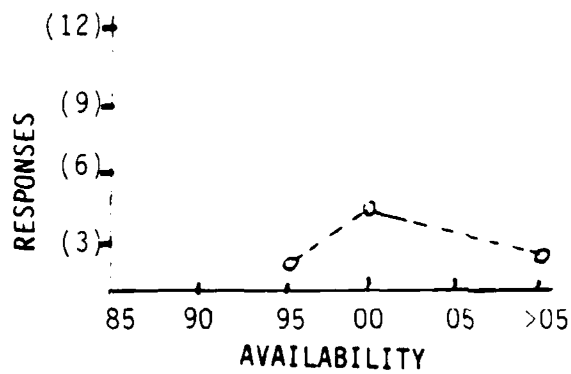
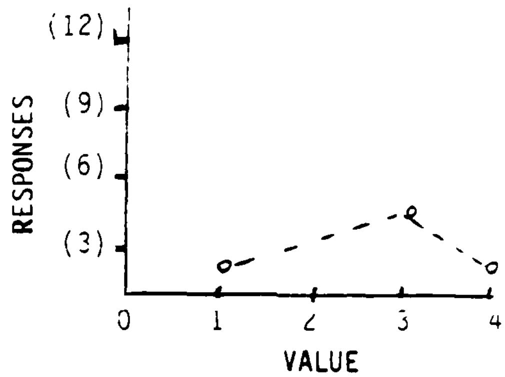
#H-4 SUPERSONIC COMBUSTION FOR HIGH MACH NUMBER AIR BREATHING PROPULSION





NEEDED DEVELOPMENTS:

- Materials for prolonged temperature exposure above 4000^{o}F.
- Fuels research other than hydrogen.
- Propulsion research for sustainer engines for acceleration to M=4.
- Methods for stabilizing hydrocarbon fueled flames for typical mission conditions must be established.
- Shock mixing and flame stabilizatin interactions must be understood.
- Feasibility demonstrated for M $\leq$ 12.
- Technology available for modular engines for M ~6.
- Difficult to proceed with "element" demonstration - milestones are for progressive demonstration of modular engines for M=8, M=10, etc.
- More investment in test programs like NASA Langley R.C.
- Flight test demonstration of promising concepts.
- Demonstration of best cooling concept.
- Improved understanding of finite rate combustion.
- Combustion analysis, fundamental kinetics and development of practical hardware.

APPLICATIONS:

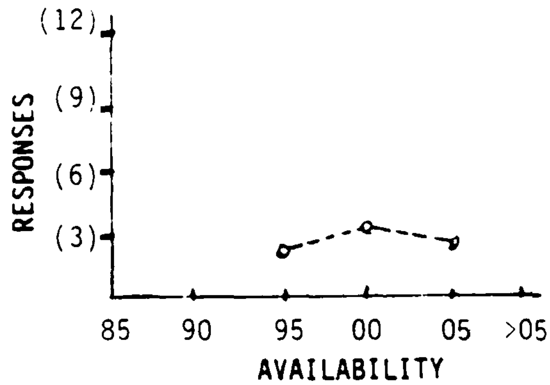
- Air breathing missiles M>6.
- Hypersonic aircraft M>6.
  Space booster stages M>6.
- Tactical missile first, then manned A/C and transatmospheric vehicles.

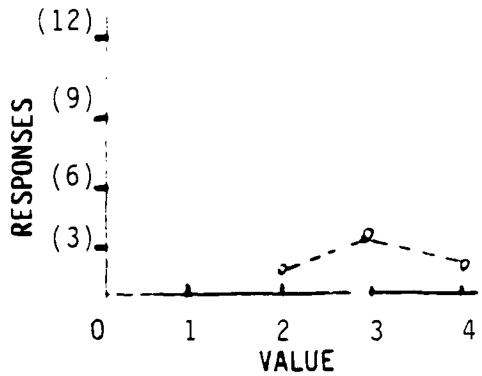
- Hypersonic transport.
- Boost stages of transatmospheric vehicles (space shuttle boost).
- Hypersonic cruise vehicles (e.g. reconnaissance).

CHOSEN BY:

Mobility

#H-15 ATTAINMENT OF SUPERSONIC FLIGHT WHICH IS ECONOMICALLY COMPETITIVE WITH PRESENT SUBSONIC TRANSPORTS





NEEDED DEVELOPMENTS:

- Devise and demonstrate integrated aeroconfiguration-propulsion system that maximizes Broquet factor.
- Unsteady 3-D transonic aerodynamics (codes, measurements).
- Fuselage designs/configurations integrated with lifting surfaces for greater lifting body contribution.
- 3-D juncture flows and shock wave/boundary layer interaction.
- Improved high temperature materials for gas turbine engines and improved understanding of supersonic combustion.
- High - re, tunnel tests of the best.
- Refined theoretical design.
- Flight demonstration at a reduced scale.
- Investigation of environmental impact of high altitude flight.
- *This is state of the art and not military.*

APPLICATIONS:

- All aircraft.
- Commercial and military transport aircraft.

CHOSEN BY:

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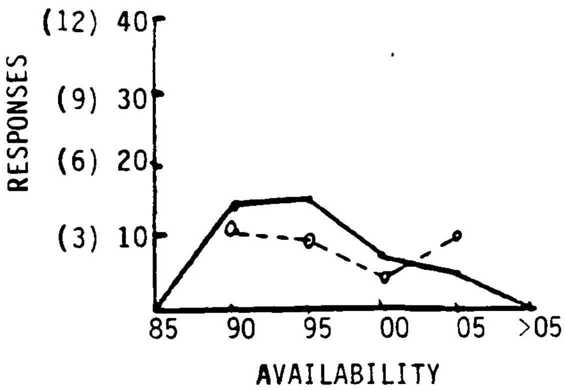
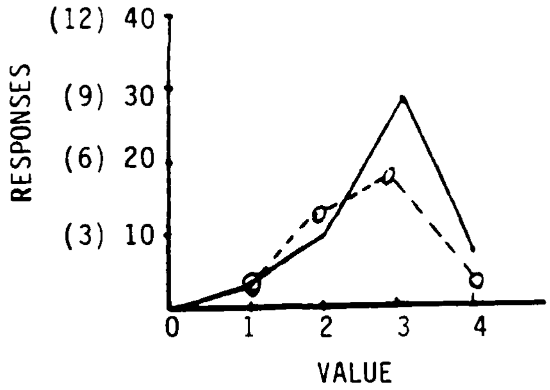
I-1 CONDUCTING POLYMERS FOR "ALL-PLASTIC" BATTERIES AND LIGHTWEIGHT ELECTRONICS





NEEDED DEVELOPMENTS:

- Develop better conducting polymers.
- Determine whether the conducting polymers can be utilized for electron storage.
- Improved stability undercycling of electrodes and electrolyte systems.
- Better processability for the polymers.
- Greater understanding of electronic energy states for polymers.
- Better calculations regarding large molecules and better understanding of metallic ion intercalation in layered and striated materials.
- Improved theoretical modeling of electronic conduction in organic materials.
- Synthesis of new, environmentally stable, organic materials that are potential conductors.

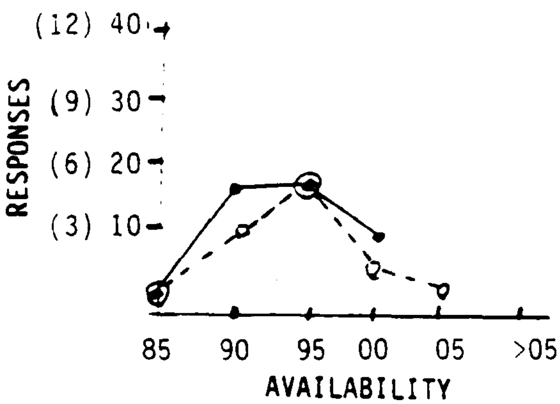
APPLICATIONS:

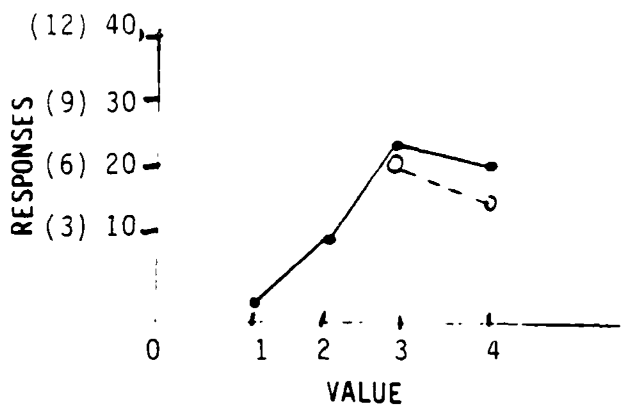
- High energy density batteries for mobile systems.
- Plastic could be used as electrolyte in all solid state batteries.
- Lightweight and rugged RFI shielding and enclosures.
- Lightweight electronics for space vehicles.

CHOSEN BY:

S & S/E.W. and C^3

#I-3 FIBER REINFORCED CERAMICS FOR HIGH STRENGTH APPLICATIONS AT HIGH TEMPERATURES





NEEDED DEVELOPMENTS:

- Continue to reduce brittleness in lab.
- Test specimens of ever increasing size and complexity.
- System tests in gas-turbine engines, etc.
- Ways to bond refractory metal fibers to ceramics and isostatic press the mass *without buckling the fibers.*
- Understanding of the role of the interface and its application to improved toughness.
- Determination of the minimum necessary fracture toughness and strengths (fatigue, long-term, high-temperature) necessary for application.
- Development of glass or ceramic matrices which can be processed into homogeneous, reproducible composites and which will survive the operating environment.
- Development of economic fibers with suitable high temperature and oxidation resistance for the application.
- Significant improvement in fracture toughness of specific materials must be achieved.
- Reduce cost of manufacturing high performance ceramics and carbon fibers. Improve technology for ceramic fibers.
- Identify fiber-matrix materials that will be compatible at high temperatures.
- Optimize fiber-matrix surface attachment; improve cross-ply strength in 2-D composities; use new ceramic fibers - e.g. silicon nitride; compatible fiber coating; matrix fabrication for 3-D composites; CVD methods.
- Fracture mechanics research in fiber-reinforced ceramics.
- Understanding of toughness and creep under repetitive loading and thermal cycles.
- Gain boundary understanding and control.

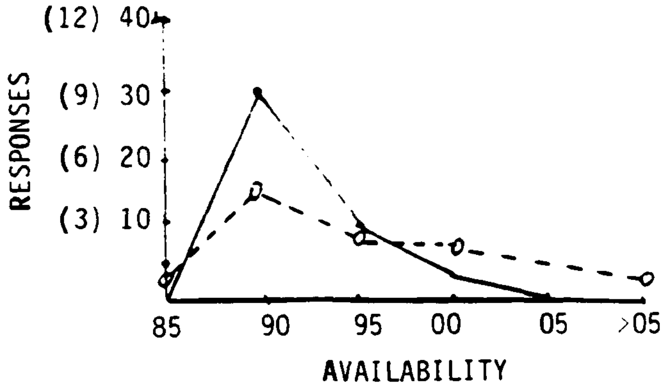
APPLICATIONS:

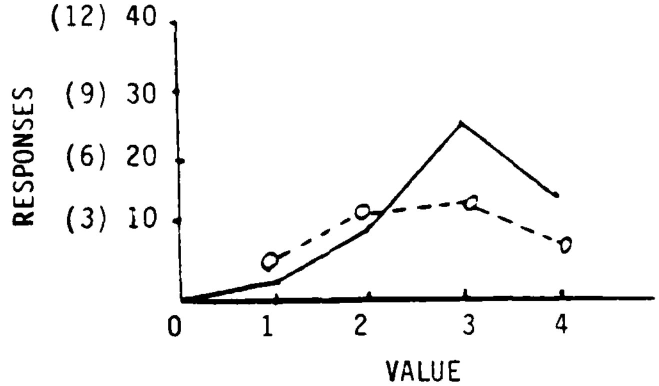
- Higher inlet temperatures produce more efficient engines.
- Lubricationless engines and bearings.
- Increase the thermal efficiency of turbines and engines by 20% (?)
- High temperature chemical processing.
- High temperature gas turbines, adiabatic diesels.
- Toughening of ceramic electrolytes which can be used in high temperatures.
- Lightweight, high strength refractory components for missiles, rockets, aircraft engines, guns , furnace liners, etc.
- Turbine engine components, blades; mirror substrates; gun barrel liners, non-corroding marine and gasification structures; lightweight structural materials for oxidizing atmospheres.
- Hypersonic aircraft, key energy generation systems.
- High temperature, and therefore high efficiency, heat engines.

CHOSEN BY:

Mobility

#I-6 METAL MATRIX COMPOSITES FOR HIGH STRENGTH-TO-WEIGHT





NEEDED DEVELOPMENTS:

--Stable fiber/matrix interface; good load transfer. Higher temperature matrix (e.g., titanium alloys).

--Improved fabrication methods for 3D composites. Stable graphite/metal interface.

--Studies aimed at gaining a better understanding of how alloying affects mechanical and corrosion prop. of MMC.

--Understanding of grain boundary/processing.

--Determine compositions which improve mechanical properties without degrading other properties of ceramics.

APPLICATIONS:

--Lightweight structures/aerospace, bridging, armaments, gun barrels, EM rail gun structures and componenets.

--Significant improvement in fracture toughness of structural ceramics for use at high temperatures.

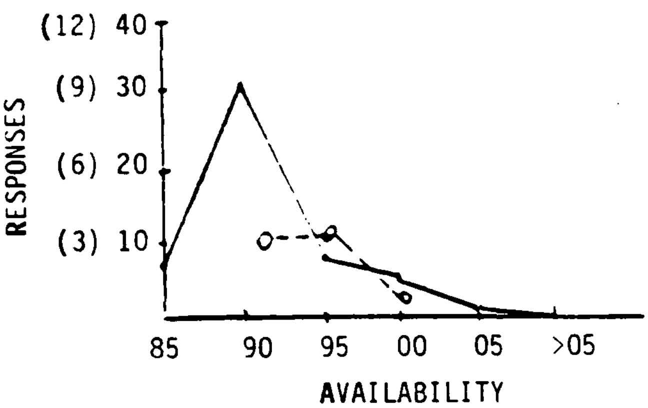
--Aerospace materials, marine applications, and transportation.

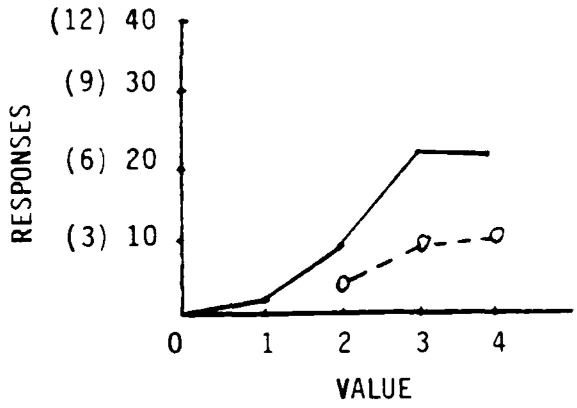
--VHSIC heat sink with therm. exp. compatibility, high stiffness, and lightweight enclosures.

CHOSEN BY:

Directed Energy, S & S/E.W.

J-1 ULTRA LOW LOSS FIBER OPTICS





NEEDED DEVELOPMENTS:

- Reduction of the impurity density in fibers. The flouride fibers are promising. The λ^{-4} scattering limitation should be achieved at 2.0 μm, then 3 μm, then 4 μm.
- A reliable fiber drawing process for materials which are far less tractable than SiO_2.
- An ability must be demonstrated to draw long fibers (i.e., a kilometer or longer) which have optical losses within an order of magnitude of the theoretical limit.
- Must demonstrate ability to make long (>10 km) fiber from low loss material.
- Reduction of Rayleigh scattering.
- Zero dispersion at wavelength of use.
- Reduction of any absorbing impurities.
- Related engineering must be accomplished, such as couplers, modems, and very efficient repeaters.
- Control of glass manufacturing and availability of practical lasers of the correct wavelength.

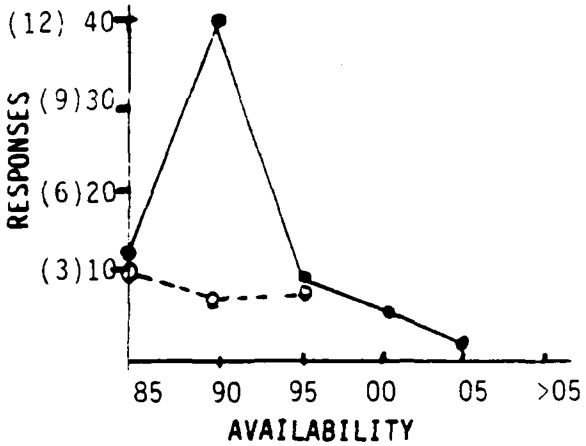
APPLICATIONS:

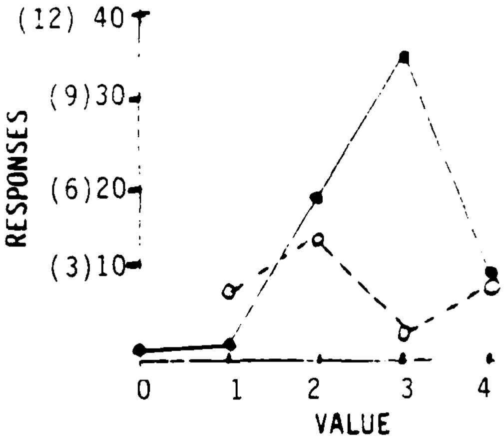
- Long repeaterless transmission links. This has many Navy applications, including, e.g., long-haul undersea acoustic surveillance.
- Large area sensor networks.
- Long distance communication (inter-city), field use for military communication, 70W missile type applications.
- Trans-Atlantic and trans-Pacific undersea cables without repeater. Will make communication satellites obsolete. Snesors and communication ports throughout the oceans.
- Long distance secure communications and anti-submarine warfare.

CHOSEN BY:

S & S/E.W. and C^3

#J-3 OPTICAL FIBER SENSORS FOR MEASUREMENT OF PHYSICAL PARAMETERS





NEEDED DEVELOPMENTS:

- Sensors for many physical parameters have been demonstrated in benign (laboratory) environments. Needed: demonstration in tactical operational environments (e.g., hydrophones for submarine towed arrays, accelerometers for missile guidance); laboratory simulation can accomplish much of this.
- Development of stable local oscillators for heterodyne detection.
- Control of sensitivity to too many physical parameters.
- Magnetic and acoustic sensors using Faraday effect.
- Monolithic integration with microelectronics.
- Method for transforming signal of interest into signal transmitted down optical fiber.
- Techniques must be developed to dramatically improve signal-to-noise problems.
- Find way to avoid "crosstalk" from different influences.
- Minimize influence of external noise sources (temperature, magnetic field, etc.)
- Development of high quality, pure glass and crystal fibers.
- Improved optoelectronic materials.

APPLICATIONS:

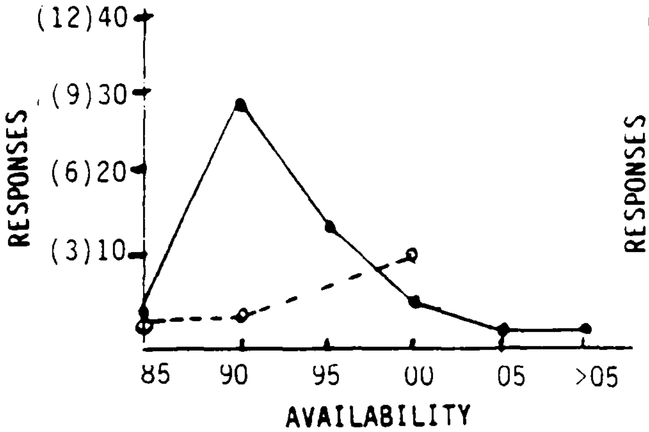
- Low cost, multi-sensor tactical and stratetic passive sensing, guidance, control and navigation.
- Will allow for optoelectronics development in which optical input into computer is followed by very fast computer control of process from which measurements originate.
- Sense acceleration, sound (antisubmarine warfare), broadband EMP and microwave power.
- This is still a "niche" technology. There are size, ruggedness, and multiplexing advantages for industrial control.

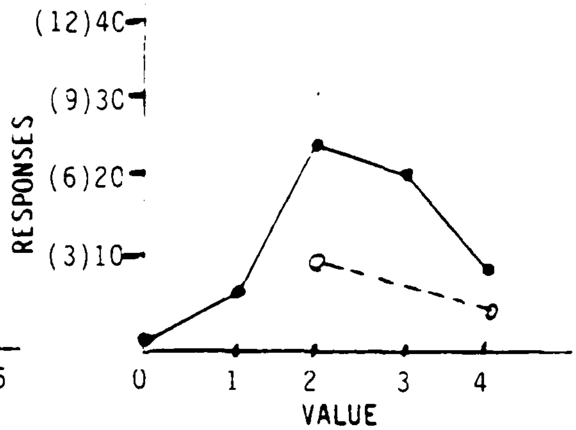
- Sensitivity and cost are attractive compared to other transducers (sensors).
- Miniature rugged sensors for many parameters.
- Ultra sensitive detection of magnetic field, stress, temperature, humidity, rotation, and acoustic signals.
- Measurement of strain, contraction, expansion and electromagnetic fields.
- Acoustic sensors in ASW.

CHOSEN BY:

Manufacturing and S&S/EW

#J-4 OPTICAL FIBER SENSORS FOR MEASUREMENT OF CHEMICAL PROPERTIES





NEEDED DEVELOPMENTS:

- Understanding of chemical bonds at a surface.
- Good chemical specificity - identification of unique chemical influences on optical fibers.
- Crude ones are available now; need materials developed for selected species; must solve draft and interference problems; must develop coating techniques for sensor materials onto opical fibers.
- Transducter to transform chemical properties into optical signal.
- Demonstration in tactical operational environments; laboratory simulation can accomplish much of this.

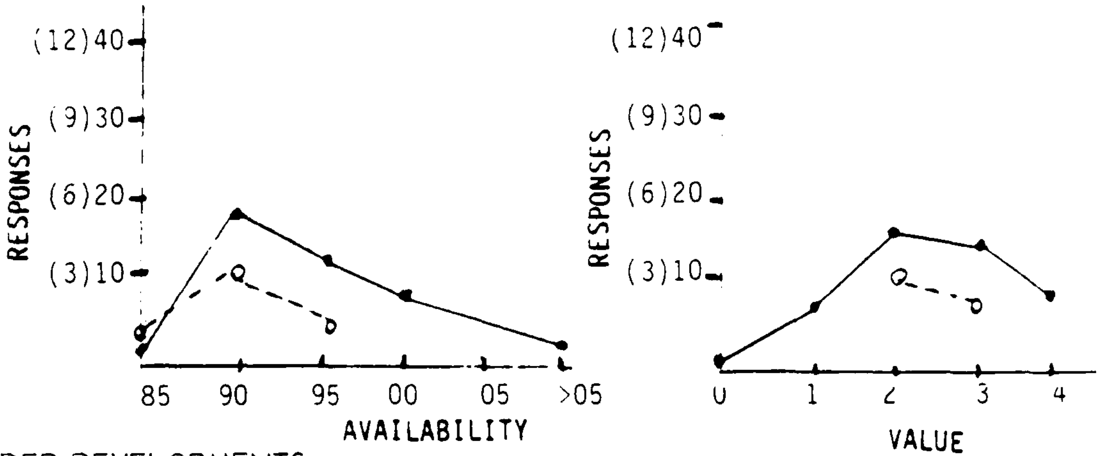
APPLICATIONS:

- Remote chemical/biological warfare sensing.
- Optoelectronics, including computer control of chemical process.
- Hydrogen scanning.
- Hostile environments/remote sensing: use where electric wires cannot be used.
- Still a "niche" technology; size, ruggedness, multiplexing advantages for industrial control.
- Sensing of atmospheric or oceanic chemical species.
- Remote sensing of chemical species with good specificity.

CHOSEN BY:

Manufacturing

#J-5 REAL-TIME HOLOGRAPHIC INTERFEROMETRY THROUGH FIBER OPTICS



NEEDED DEVELOPMENTS:

- *Solution to the basic problem of image transmission in fibers.*
- Coherent single mode fibers and fiber arrays.
- Fiber optic dividers, modulators.
- System development, especially sensor for long wavelengths and conversion of data to visible images.
- Innovative data processing that is rapid enough for "real-time" work.
- Demonstration in real working environments.

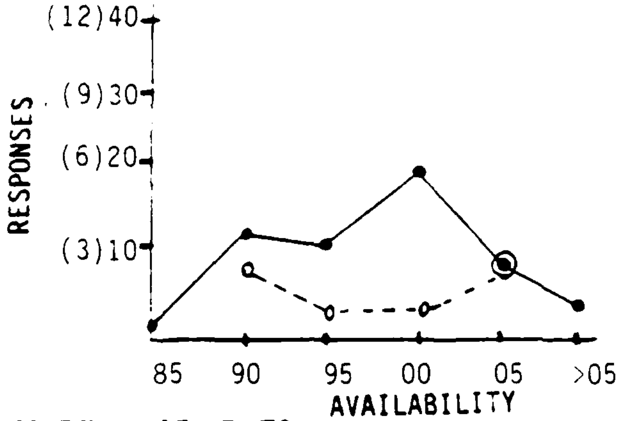
APPLICATIONS:

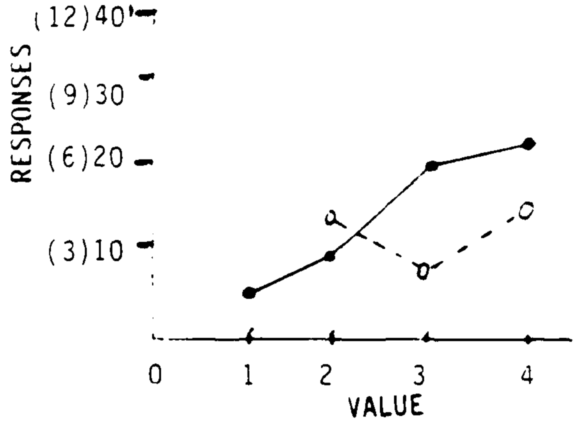
- Real time imaging with wavelengths long compared to visible light wavelengths.
- Vibration analysis of complicated structures; convenience of transport.
- Limited "internal" testing of apparatus.
- Robotics vision; quality control.
- Real time operational holography for diagnostics, without present size, handling and packaging constraints.
- Optical testing.

CHOSEN BY:

Manufacturing

#J-6 COHERENT GAMMA-RAY SOURCES (E.G., X-RAY LASERS)





NEEDED DEVELOPMENTS:

- Efficient pumping by realistic sources, repeatable operation.
- Development of pump sources other than atomic bomb.
- This is available now as bomb-pumped or NOVA laser pumped devices.
- Laboratory-scale, X-ray laser without excessive pulsed power pumping.
- Development of sufficiently simple and economical ways to upgrade visible coherent sources into gamma or X-ray range.
- The development of a controllable laser medium in this wavelength regime.
- There has been impressive progress recently in this area.

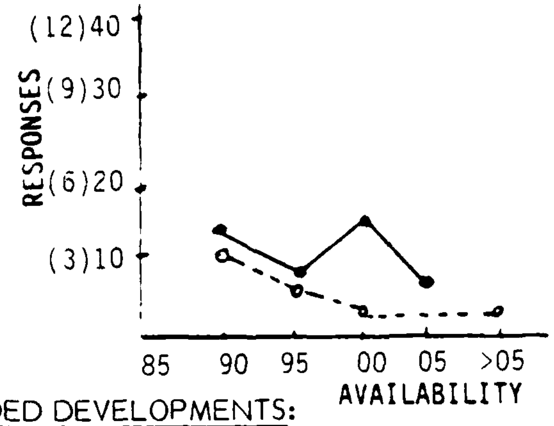
APPLICATIONS:

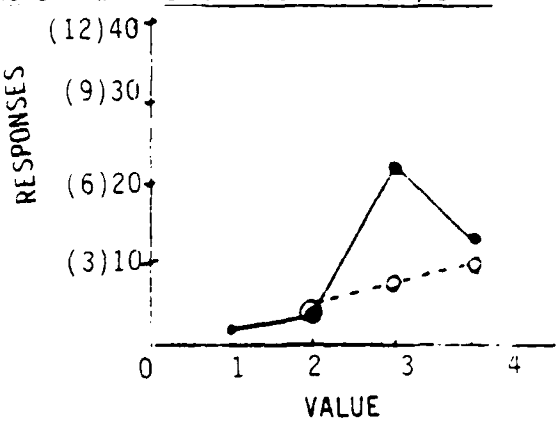
- Vast improvement in diagnostic radiology.
- X-ray (sub 0.1 micron) lithography for VLSI.
- X-ray holography.
- SDI, biological/medical applications.
- Crude holography.
- Testing of weapons effects.
- Science of nuclear levels, remote sensing.
- X-ray, microscopy, medical, solid state, and other applications.
- Fundamental research; communications; missile destruction.

CHOSEN BY:

Directed Energy

#J-7 STEERABLE LASER DIODE ARRAYS AT POWERS OF APPROXIMATELY 1 KW/CM^2





NEEDED DEVELOPMENTS:

- The important issue is how many kW (10^2, 10^3) in a coherent aperture.
- 1 kW/cm^2 on a pulse basis -- 1986-1990.
- 1 kW/cm^2 C.W. or average without either fiber optics to compress beam size or antenna to focus beam -- never.
- Steerable -- 1991-1995.
- Precise phase control mechanisms.
- Electronic mode control or monolithic electro-optic phase control.
- Face (?) emitting laser diode arrays with EO modulator as integral part.
- Growth of surface-emitting (top) layer diodes.
- Stacking linear arrays.
- Construction of large arrays.
- Increase operational life of such arrays.
- Use of quantum well technology to get interest up.
- Heat sinking and power dissipation technology.
- Large scale, high yield manufacturing.
- Required breakthrough has occurred at Lincoln Labs.

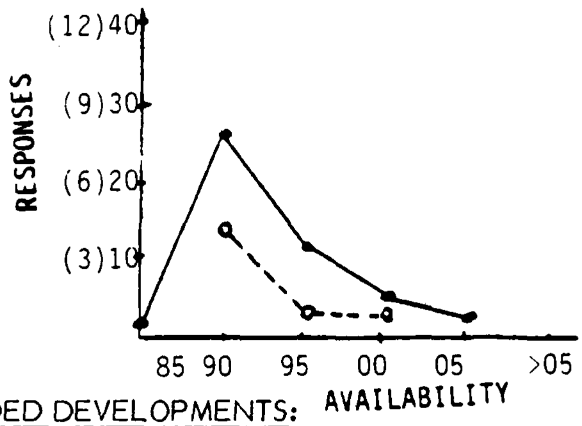
APPLICATIONS:

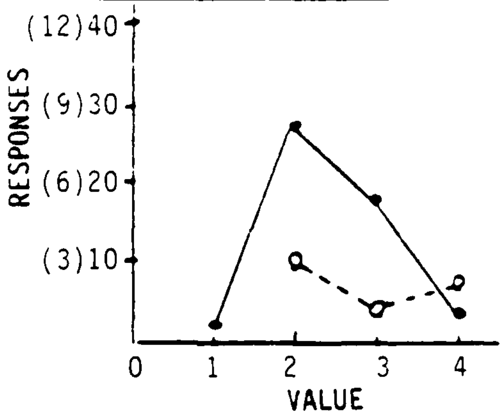
- Remote sensing; medical applications.
- Laser radars.
- Materials processing, antiaircraft weapons.
- Projected guidance.
- Optical printing; optical radar.
- Radar; data processing.
- Space communications, SDI.

CHOSEN BY:

C^3

#J-9 Nd:YAG LASERS WITH AVERAGE POWER I kW, FOR MANUFACTURING





NEEDED DEVELOPMENTS:

- I kW at 4% efficiency was demonstrated in 1968.
- High pulse rate>200 per second.
- Power greater than I joule.
- Vast improvement in thermal control and system reliability.
- Slab geometry pumped by semiconductor arrays.
- More cost effective growth of YAG rods.
- Better heat removal technology.
- More efficient optical pumping sources (e.g., diode arrays).
- High power optics.
- Advances in pumping and cooling.

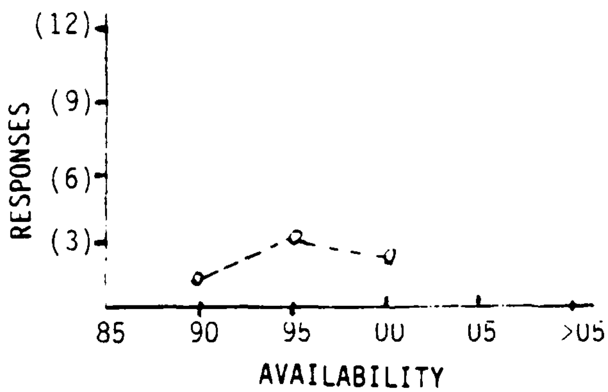
APPLICATIONS:

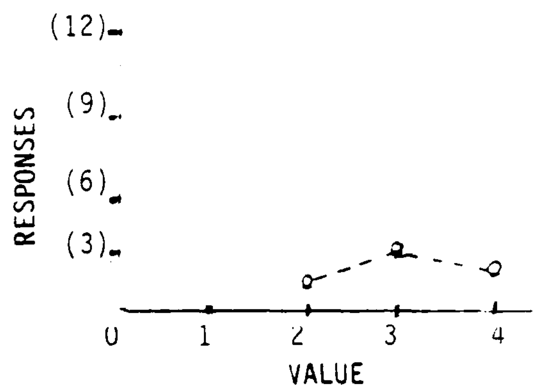
- ufacturing and anti-sensor military applications.
- Welding to close parameters.
- Material processing (welding, cutting, drilling, etc.), radar, medical.
- Communications.
- Underwater detectors.
- High purity welding.

CHOSEN BY:

Manufacturing

#J-11 MID- AND FAR-INFRARED OPTICAL FIBERS OF LOW LOSS





NEEDED DEVELOPMENTS:

- Minimize thermal sensitivity.
- Ensure that phase coherence is uniform among fibers and that it does not get attenuated.
- Better control of new flouride glass manufacturing technology.
- New glassy materials.
- High homogeneity, high purity flouride glasses in flouride form.
- Development of low loss glass in this frequency range.
- Methods of drawing fibers, etc.
- Reduction in toxicity of fibers used.
- (This is closely related to #J-1: Ultra low loss fiber optics).

APPLICATIONS:

- Military and inter-city communications.
- Medicine: endoscopy, tumor burning.
- Long distance, highly secure communication.
- IR surveillance equipment.
- Within sensors such as forward looking infrared (FLIR), seekers, etc.

CHOSEN BY:

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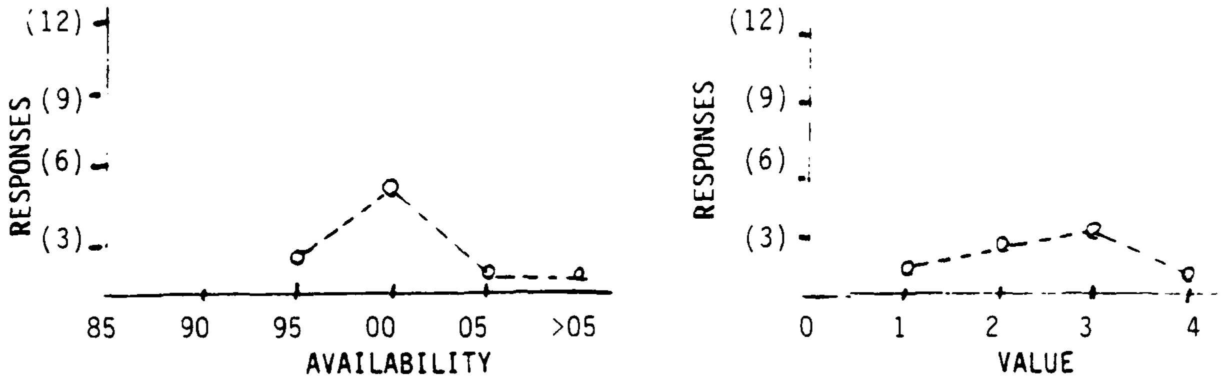
#J-12 SATELLITE LASER TECHNOLOGY FOR SATELLITE-SUBMARINE (SUBMERGED) TWO-WAY COMMUNICATION



NEEDED DEVELOPMENTS:

- Diode array development with 1 kW/cm^2 power at 35% efficiency.
- Sonar on submarine to interact with laser beam from satellite for two-way communication. (This assumes a deeply submerged submarine without an optical link to the surface and the requirement that the submarine remain covert).
- Reliable space-qualified and sharply tunable lasers.
- Efficient nonlinear conversion.
- The propagation path and detectors have been well characterized.
- Down-link demonstration (late 1980's).
- Up-link requires new lasers, better direction sensitivity and control.
- High power, efficient blue green laser.
- This is mainly an efficiency problem.

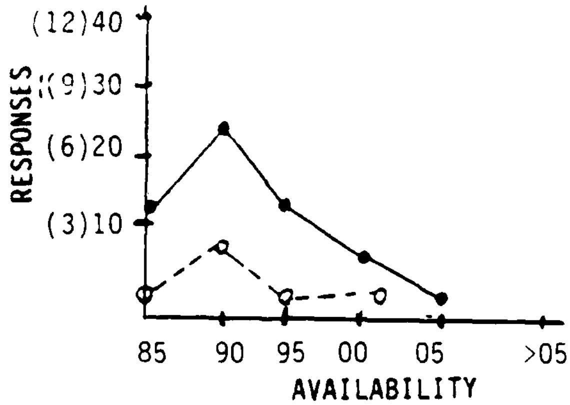
APPLICATIONS:

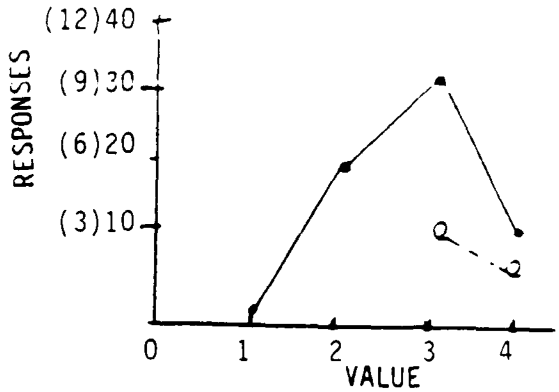
- Tactical and strategic communications between submerged submarines and other forces, as well as with the command network.
- Question: is the non-covertness of the uplink acceptable operationally to a submarine?
- Underwater communications; mapping.
- Optical memories; color displays.
- SUBACS
- Secure (?) communications to compete with VLF, ELF.

CHOSEN BY:

C^3

#K-3 ACOUSTIC IMAGING FOR RECONNAISSANCE OF THE INTERIORS OF STRUCTURES AND NONDESTRUCTIVE TESTING





NEEDED DEVELOPMENTS:

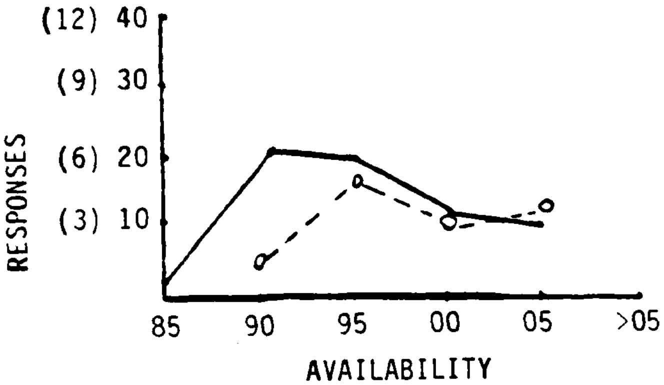
- Imaging for interiors of structures must overcome limitations of multiple surfaces and reflections from internal voids and cavities.
- High frequency transducers; good signal processing method.
- Gain experience in resolution and penetration.
- Capability for acoustic imaging for nondestructive testing is available and in use for inspection.

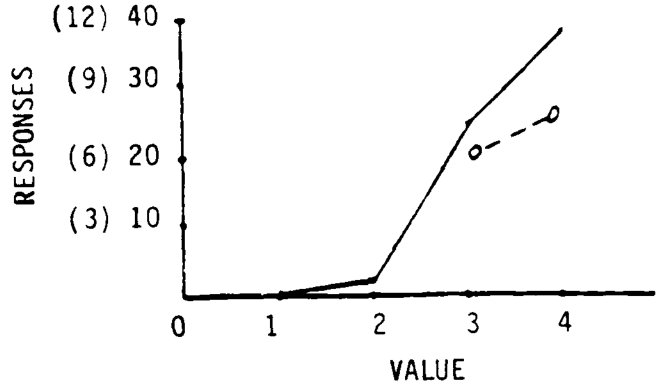
APPLICATIONS:

- Medical, biological and geological engineering.
- Rapid testing procedures.
- Mapping defects in composites.
- Inspection during fabrication.
- Radome diagnostics.

CHOSEN BY:

Manufacturing





NEEDED DEVELOPMENTS:

--Approximately greater than 2 orders of magnitude increase in computer performance.

--Conceptualization and design of reliable algorithms and design of efficient hardware.

--Greatly improved understanding of representation issues in order to go much beyond existing simple approaches.

--More use of application-specific knowledge coupled with more computing power.

--This area is at the threshhold of realizability. AI techniques should be married to well developed pattern recognition techniques and use of very high speed fifth generation machines.

--Knowledge representation language specifically adapted to this application.

--General availability of hardware for executing LISP programs, performing image analysis and transformation.

APPLICATIONS:

--Robots, manufacturing, system control, remote exploration, monitoring and security, reducing clerical work, helping the blind.

--Industrial/factory automation.

--Remote sensing analysis, SDI, target acquisition, industrial sorting.

--Surveillance and reconnaissance; battlefield management.

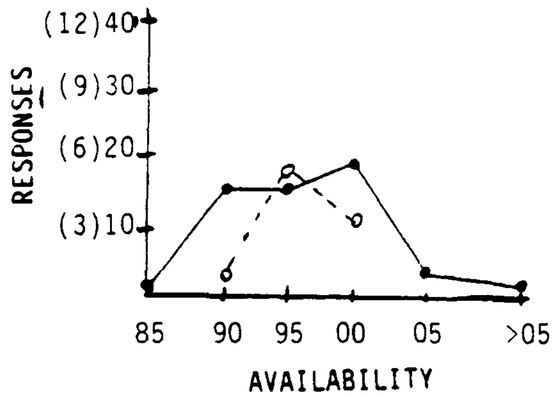
--Computer analysis of handwriting.

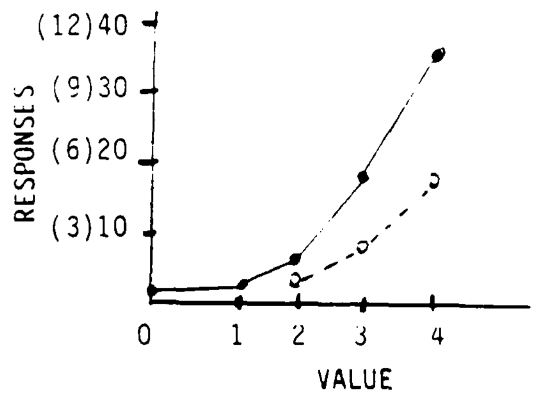
--Semiautomatic "attention requesting" monitoring systems.

CHOSEN BY:

Mission Support, Manufacturing, Mobility, S & S/EW, and C^3

#L-3 AUTONOMOUS WEAPONS VISION WITH AUTOMATIC TARGET RECOGNITION





NEEDED DEVELOPMENTS:

- Computational and inductive power must be significantly improved.
- At least two orders of magnitude improvement in computer capabilities.
- VLSI-based parallel processor/feature extractors.
- Sensor suite development; use control.
- Fast, inexpensive array processors; adaptive electro-optical processing.
- Reliable recognition algorithm.
- Automated image recognition and classification (#L-1).
- Autonomous machine vision for robot self-guidance (#L-2).
- Sufficient demonstration of #L-1 and #L-2 (above) so that rules of engagement can be constructed and accepted.
- Better modeling of realistic background, not just targets.
- Major difficulty here is that "countermeasures" are relatively easy.
- It will be a long time before there will be truly autonomous weapons, except in specific SDIO cases.

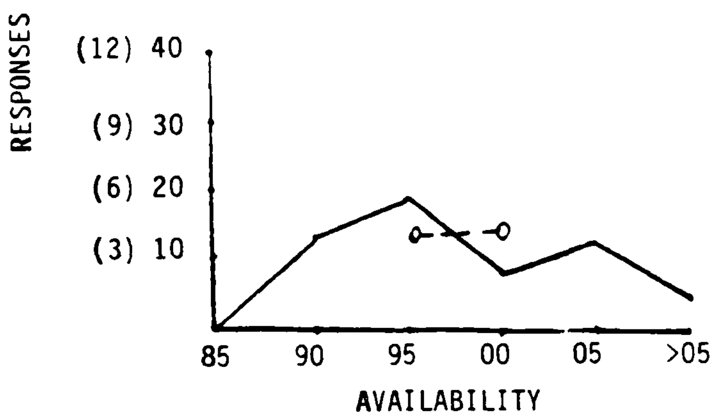
APPLICATIONS:

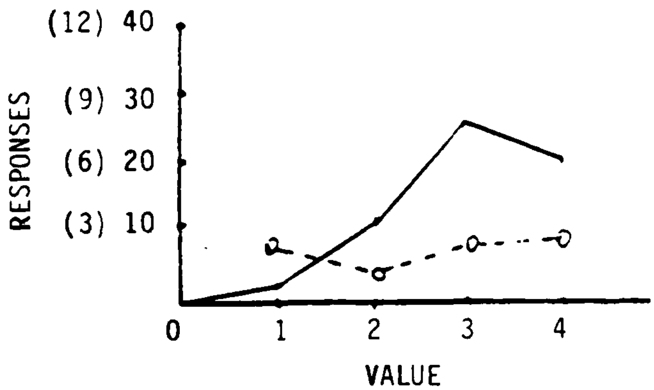
- SDI - figher aircraft, "autonomous" submarine, and other autonomous vehicles.
- Tactical warfare.
- Zero CEP weapons.
- Smart weapons - ability to use munitions for wide range of missions.

CHOSEN BY:

S&S/EW

#L-4 DEVELOPMENT OF A WORKING MODEL OF OPTIMUM ALLOCATION OF DECISIONS AND ACTIONS BETWEEN HUMANS AND MACHINES IN A MAN MACHINE SYSTEM





NEEDED DEVELOPMENTS:

--Definition of optimality in realistic man-machine systems; algorithmic design; and efficient control hardware.

--We will probably see steady growth in this type of area simply through expert system development. To a considerable extent the technology already exists in rudimentary form.

--Partitioning overall problem into solution techniques that can be automatically scanned to choose optimum hardware/software utilization

--This is the control problem for distributed, heterogeneous systems--it has appeared several other places.

--Validated human performance models for specific application domains.

--Need experience with specific applications that will push the hardware/software/conceptual resources.

--Questions about who does what best need to be investigated and codified. One principle is that it is desirable to take man out of the "direct-action" loop, and let his contribution be supervisory (e.g., man decides where and when to land the aircraft, and the automatic landing system makes the landing).

APPLICATIONS:

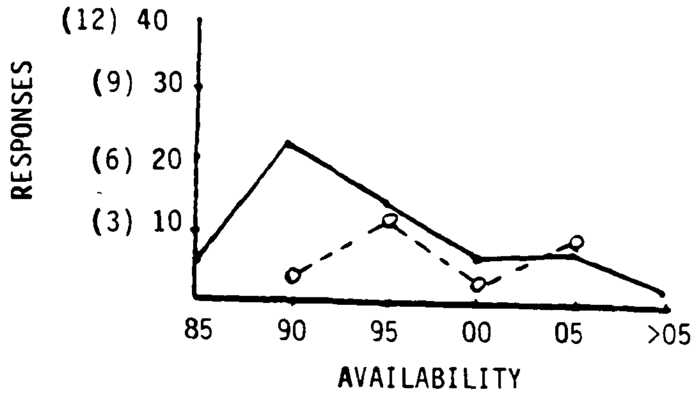
--Airline operation, nuclear power reactor applications, etc.

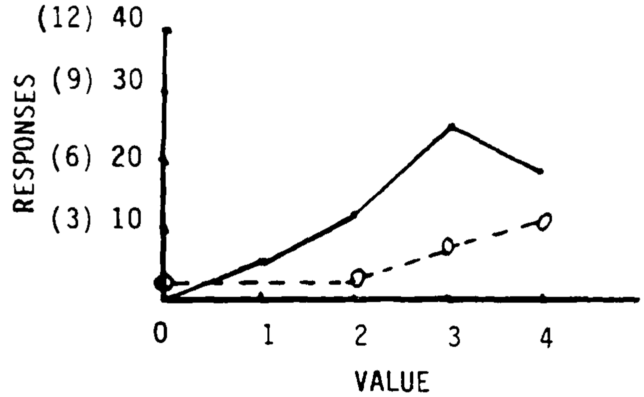
--Military and industrial systems.

CHOSEN BY:

Manufacturing, Mobility, S&S/EW, and C^3.

#L-6 AUTOMATIC UNDERSTANDING OF SPEECH OF A SPECIFIC INDIVIDUAL





NEEDED DEVELOPMENTS:

--10x improvement in algorithms; 100x improvement in computer power.

--Principles of speech recognition under realistic day-to-day conditions and vocal changes; "learning" processes. Efficient hardware design.

--For automatic understanding we will need hugely different non-von Neumann architectures of bizarre complexity.

APPLICATIONS:

--Speech typewriter.

--Vocal control of computer systems.

--Security; C^2.

--Controlless cockpit.

--Reduction in clerical manpower in administrative functions.

--Help for machine operator, fighter pilot, busy executive, etc.

CHOSEN BY:

Mission Support, Manufacturing, Mobility, and C^3.

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APPENDIX 8

PLANNING MEETING FOR ET WORKSHOP AND SESSION CHAIRMEN—AGENDA

APPENDIX 8

OSD EMERGING TECHNOLOGIES PROGRAM

PLANNING MEETING FOR ET WORKSHOP AND SESSION CHAIRMEN

15 MAY 1985

Agenda

0900	-	Welcoming remarks; Introduction of principals; Overview of SAIC ET effort; Purpose of meeting--Bob Cronin (SAIC)
0910	-	Introductory remarks, and OSD's Emerging Technologies Program--Dr. Leo Young, Dr. Paris Genalis (OSD/R&LM)
0925	-	SAIC Emerging Technologies effort (Background; Delphi; Workshop; Panels)--Dr. George Gamota (U. Michigan and SAIC consultant)
0940	-	Delphi process (Survey development; Technologies identified to date)--Dr. Joel Bengston (SAIC)
1015	-	**BREAK**
1030	-	Begin first-cut selection of technologies by the six Session Chairmen--All
1200	-	**LUNCH** (served in the conference room)
1245	-	Continue first-cut selection of technologies by the six Session Chairmen--All
---		Detailed discussion/explanation in response to questions of Chairmen; Decide "protocol" of Workshop--All
1430	-	Definition of Workshop Session "results"--All
1500	-	Concluding comments--Dr. Willenbrock
1515	-	**ADJOURN**

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APPENDIX 9

EMERGING TECHNOLOGIES WORKSHOP—AGENDA

APPENDIX 9

EMERGING TECHNOLOGIES WORKSHOP

17-19 JUNE 1985

Agenda

Monday, 17 June 1985

0830 - Sponsor's final planning meeting with Chairmen and SAIC

0930 - Plenary meeting of all attendees
- Introduction of program and principals
- Comments/Overview by ET Sponsor, Workshop Chairman, and SAIC

1000 - Summary of Delphi data by SAIC

1200 - **LUNCH**

1330 - Convene six "Areas of Application" Sessions (individual, concurrent meetings)
- Session members digest Delphi results
- Session Chairmen organize their groups' approach
- Session Chairmen assign individual review responsibilities

1630 - **SESSIONS ADJOURN**

1630-1730 - Sponsor's Meeting with Session Chairmen

Tuesday, 18 June 1985

0900 - Continue individual session work

1200 - **LUNCH**

1330 - Continue individual session work

1630 - **SESSIONS ADJOURN**

1630-1730 - Session Chairmen finalize summary results

Wednesday, 19 June 1985

0900 - Re-convene plenary meeting
- Session Chairmen present summary results for each "Areas of Application"
- Concluding discussion and comments by Sponsor, Workshop Chairman, and SAIC

1300 - **ADJOURN**

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APPENDIX 10

PROTOCOL FOR OSD EMERGING TECHNOLOGIES PRIORITIZATION WORKSHOP

APPENDIX 10

PROTOCOL FOR OSD EMERGING TECHNOLOGIES PRIORITIZATION WORKSHOP

17-19 JUNE 1985

United States Naval Academy, Annapolis, Maryland

Definitions

1. Emerging Technology: The earliest form of technology, i.e., technology which is moving beyond the basic research and scientific principle stage into a state in which it can be used to create a production process or a product.

   For the purposes of this Workshop, we are focusing upon those emerging technologies of particular utility to the military Services.

2. Ranking of Technologies: To prioritize those emerging technologies of highest potential for DoD or other government investment, in view of Workshop time constraints, each "Area of Application" session is requested to:

   a. Divide your list of emerging technologies (ETs) into halves--the lower half consisting of those ETs deemed by the Session to be of relatively lower priority, and the upper half consisting of those ETs of higher priority. The lower half will not be further addressed by this Workshop.

   b. Rank order the upper half ETs into two lists--an upper quarter "A list" and second quarter "B list."

   c. For each of the "A list" and "B list" ETs, prepare a two-page briefing paper addressing "Description," "Status," "Application," and "Impact" as described under "CONTENTS OF ET BRIEFING PAPERS" (p.2).

   d. If in addition to the ET list provided to you, your session feels strongly that items of highest priority are not included, please provide those ETs in the same format as in 2(c).

3. Time Estimates: In addition to the possibility of estimating the year by which an ET milestone may be achieved, "time" can also be expressed in relation to dependence upon the achievement of a predecessor technology. For example, "Technology 'Z' can achieve Status Milestone (2) two years after Technology 'Y' achieves Status Milestone (3)."

CONTENTS OF ET BRIEFING PAPERS

1. DESCRIPTION

Describe each emerging technology in one-half page:

a. Describe it in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

b. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2. STATUS

Describe the status of work at organizations which are actively involved in developing this emerging technology:

a. Estimate time availability of the technology (i.e., when will it be available for inclusion in a product or production process?).

b. Estimate US status compared to any non-US work being done on the ET in question.

c. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

d. Use the tabular form below to identify important milestones in the emergence and development of this technology.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First experimental device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3. APPLICATIONS

Describe the potential military applications of this ET:

a. How might it be used?

b. To what products or processes might it be applied?

4. IMPACT

Estimate the potential military impact of this technology:

a. How might the technology in question change US military capabilities?

b. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Reporter: ____________

Aided by: ____________

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SAMPLE EMERGING TECHNOLOGY (ET) BRIEFING PAPER

Photo-Recording Materials

1. DESCRIPTION

a. The limitations of recording materials used to interface electronic signals and optical processors have precluded widespread usage of optical signal processors. Existing materials (photographic film, KD*P) do not allow simultaneous rapid development, large space-resolution product, wide time bandwidth product, and high sensitivity. At NRL, techniques have been developed to fabricate high quality photodichroic materials which do allow simultaneous achievement of the above characteristics. Samples have displayed a Modulation Transfer Function (MTF) of approximately 100 line pairs/mm at 25% response, sensitivity of 10 mj/cm^2 and crystal sizes sufficient for space bandwidths of 10^7 or better. Other reversible photo-recording materials are under investigation elsewhere.

b. The crystal or material facilities for manufacturing the recording materials are in existence or could be realized within, say, a few months. The processing concepts have in the main existed for some time and could be implemented quickly when the needs and materials are defined.

2. STATUS

a. Probably within the next five to 10 years a material of preference will emerge.

b. Technology in the above particular photodichroic material is largely restricted to the Naval Research Laboratory. Other materials and devices seem to be far more highly developed abroad, principally in the Soviet Union and France.

c. US experience with the material $Bi_{12}SiO_{20}$ (the ITEK PROM material), contrasts poorly with the reported success the Russians have had with $Bi_{12}GeO_{20}$. The United States may utilize materials of this type in about 10 years. Devices/systems will be in the general area of signal processing by optical means. These include HF/RF spectrum analyzers, large array acoustic signal processors, and Fourier transform analyzers.

d.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1983	US NRL
2. First experimental device application (or first experimental process demonstration)	1984	US France USSR
3. When available for inclusion in product or process?	1995	US

3. APPLICATIONS

a. At present, NRL photodichroic medium offers a solid state material which can be recycled almost indefinitely at about -10^{o} C. This will make possible a number of exotic signal processing systems with application to radar signal processing, signal delay, real time adaptable filters, acoustic signal processing, etc.

b. Processing by optical means could bypass shortcomings in electronic signal processing for certain military applications. For competition with advanced LSI electronic processing, the advantages for optical processing remain somewhat undetermined.

4. IMPACT

a. Impact is not fully identified, but expected to be generally similar to 3a.

b. In addition, technology could substantially improve US target acquisition and tracking capabilities.

Reporter: ____________

Aided by: ____________

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APPENDIX 11

LIST OF ETS CHOSEN BY SESSION CHAIRMEN/CHOSEN AT WORKSHOP

APPENDIX 11

LIST OF ETS CHOSEN BY SESSION CHAIRMEN/CHOSEN AT WORKSHOP

Command, Control and Communications

"A" list:

1. Three protocols on:
   - Battery technology: Nickel Aluminum, Iron Air, Iron Silver, Lithium, Nickel Cadmium, and Conducting Polymers
   - Long lived, high energy density batteries
   - Conducting polymers for batteries, antistatic packing and other applications

   incorporating:
   - Long lived batteries for space application (C-16)
   - High power, high energy density batteries (C-17)
   - Conducting polymers for "all-plastic" batteries and light-weight electronics (I-1)
2. Distributed automatic control of a communications network and link parameters in a hostile environment (D-8)
   (Three protocols submitted)
3. Automatic generation of software from natural language (E-1)
   (Two protocols submitted)
4. Parallel processing technology;
   incorporating:
   - Parallel processing based on optical communications between N processors and M memories (not necessarily chip-to-chip optical interconnections) (E-2)
   - Parallel processing based on novel interconnect hard wired (non-optical) schemes (e.g., "cosmic cube" architecture) (E-3)
   - Highly parallel architecture based on systolic chips (E-6)

   related items:
   - Computer language which is really appropriate for parallel processing (E-7)
   - Automatic mapping of signal processing algorithms described in high level language onto specific multiprocessor architecture or VLSI configurations (D-3)
5. Ability to deal with large masses of data from many (10^4) sensor locations in a highly cluttered non-stationary environment, as in a distributed system (E-8)
6. Design principles for substantially improved reliability of electronic systems (G-17)
   (two protocols submitted)
7. Ultra low-loss fiber optics (J-1)
8. Automated image recognition and classification through use of AI techniques (L-1)
9. Development of automated function allocation between man and machine in complex C^3 systems;
   incorporating:
   - Optimum allocation of decisions and actions between humans and machines in a man-machine system (L-4)

"A" list (cont.):

10. Speech recognition;
    incorporating:
    - Automatic understanding of speech of a specific individual (L-6)
    - Automatic understanding of speech of a general class of individuals (L-7)

11. Threshold logic for decision making in situations of incomplete information (L-17)

12. Decision support system for military decision making (e.g., for efficient task assignment and efficient procurement procedures) (L-18)
    (Two protocols submitted)

13. High power, compact mm wave antennas with distributed sources (D-4)

14.* Automatic mapping of signal processing algorithms described in high level language onto specific multiprocessor architecture or VLSI configurations (D-3)

15. A-D/D-A converters;
    incorporating:
    - High performance A/D conversion for recording and signal processing (e.g., 16 bits-5 MHz; 8 bits-500 MHz) (D-6)

16. Computer language which is really appropriate for parallel processing (E-7)
    (Two protocols submitted)

* No protocol submitted

Command, Control and Communications (cont.)

"B" list:

1. Synergistic monitoring of human/machine operational readiness; incorporating:
   - Sensors for monitoring changes in human alertness and vigilance (A-20)
   - Man-machine mutual monitoring loops (L-20)
2. Millimeter wave radio including low noise receivers and solid state power amplifiers; incorporating:
   - Low noise mm wave receivers (D-5)
3. Computational methods using numerical and symbolic data (E-11) (Two protocols submitted)
4. Macroelectronic arrays (e.g., Flat panel displays, electronic tablets) (G-11)
5. Satellite laser technology; incorporating:
   - Steerable laser diode arrays at powers of approx. 1 kw/cm^2 (J-7)
   - Satellite laser technology for satellite-submarine (submerged) two-way communications (J-12)
6. Natural language understanding (NLU) (new topic - group L)
7. Computer security (new topic - group E) (two protocols submitted)
8. Advanced communications switching techniques (new topic - group D)
9. Molecular-scale electronic circuit elements - quantum well structures and devices; incorporating:
   - Molecular-scale electronic circuit elements and conductors (G-3)
10. Chemical microsensor; incorporating:
    - Sensors for monitoring changes in human alertness and vigilance (A-20)
    - Molecular-scale electronic circuit elements and conductors (G-3)
    - Automated chemical analysis using robotics, for laboratory or manufacturing plant (L-8)
11. Synthetic nonlinear optics materials custom designed for specific applications (e.g., optical computer elements) (G-1)
12. Development of unmanned, remotely addressable under water vehicles (L-10)
13.* Two-way address selectable, fiber optic video/phone/data networks (D-9)

* No protocol submitted

"B" list (cont.)

14.* High-speed computers--parallel and array processors in compact portable modules (i.e., desk-top Crays) (E-13)

15.* Hardware-software interfaces for computational techniques for control, stabilization and identification of large distributed parameter systems--specifically use of parallel architectures in these problems (E-18)

16.* Integrated optical sensors/digital processing elements in a single chip focal plane array (G-4)

17.* Optical read/write recording devices (G-19)

18.* Efficient, inexpensive photovoltaic cells (C-19)

19.* Totally automated "silicon compilers" (E-12)

* No protocol submitted

Command, Control and Communications

"C" list:

1. System for detoxification of personnel and equipment exposed to biological and chemical agents without harm to personnel (A-10)
2. Multipurpose detoxifying agent against chemical warfare (A-13)
3. Enhancement of alertness on duty by circadian scheduling of naps and sleep periods (A-23)
4. Efficient, inexpensive fuel cells (C-18)
5. Development of single integrated "all-weather" visual displays for use by aircraft operator (D-1)
6. Optimum adaptive processing of limited and/or non-error-free data sets (e.g. time limited outputs of real arrays of sensors) (D-2)
7. Coherent signal processing systems for active/passive spatially dispersed sets of sensors (D-7)
8. High power spaceborne ULF transmitters for submarine communications (D-10)
9. Low cost, high speed A-D/D-A with built-in filtering (D-11)
10. Materials with reduced radar and IR signatures (D-14)
11. Antennas with low radar cross sections (D-15)
12. Air vehicles with very low observable signatures through multidisciplinary technology integration (D-16)
13. Architecture based on neuron connectivity in mammalian brains (E-4)
14. Very fast, small, inexpensive read-and-write memories (E-5)
15. Array detectors and radiator to replace mechanically moving disk and tape recording devices (E-15)
16. High performance numerical algorithms for stiff, singular, or discontinuous problems (E-16)
17. Growth of 3 and 4 components compound semiconductors of desired (specified) characteristics (G-6)
18. Coherent submillimeter wave source in the solid state (G-8)
19. Electrodeposition processes to produce materials for ICs efficiently and economically (G-9)
20. Elimination of cosmic ray interferences in microchips (G-15)
21. Three terminal solid state devices operating above 100 GHz (3 mm) for radars, communications (G-18)
22. Commercial production for Ga:As and other semiconducting materials in space (G-20)

"C" list (cont.):

23. High efficiency solar cells for space applications, especially III-V materials (G-25)
24. Lightweight (density < 2 g/cm^3) composite materials for space application--radiation, vacuum resistant (I-15)
25. Surface coating non-sticking for water and ice to prevent fogging and make de-icing unnecessary (I-19)
26. Space based system for fabrication of components for space structures (I-24)
27. Long-range weather forecasting (K-8)
28. 4-D (space and time) assimilation of remotely sensed meteorological data for incorporation into prediction models (K-12)
29. Expansion of environmental forecasting models to accept real-time satellite data for regular forecast verification and condition updates (K-13)
30. Automated onboard satellite processing of atmospheric and ocean characteristics (K-17)
31. Global measurements of magnetospheric electrical circuit for better predictions of geomagnetic storms and their effects on space systems (K-24)
32. Autonomous weapons vision with automatic target recognition (L-3)
33. Unmanned orbiting robotics vehicles for spacecraft repair and upgrade (L-13)

"A" list:

1. Prime power
2. Metal matrix composites for space structures; incorporating:
   - Metal matrix composites for high strength-to-weight (I-6)
3. Electron beams
4. Artificially structured materials for pulse power switching
5. Neutral particle beams; incorporating:
   - High-current radiofrequency quadrupole accelerators (F-1)
   - High-current, low-emittance ion sources for tritium and lithium beams (F-3)
   - Negative ion (e.g., hydrogen) beam neutralization using lasers for photodetachment (F-4)

"B" list

1. Coherent locking of laser beams; incorporating:
   - Coupled resonators for laser power scaling to high brightness (F-9)
   - Laser phased arrays for laser power scaling for high brightness (F-10)
2. Nonlinear phase conjugation techniques (F-14)
3. X-ray laser - nuclear driven
4. Short wavelength lasers (nonlinear); incorporating:
   - Coherent gamma-ray sources (e.g., X-ray lasers) (J-5)
5. Free electron lasers (FEL); incorporating:
   - High efficiency, high power free electron lasers in the near-IR or visible (F-19)

Manufacturing

"A" list:

1. High speed, high capacity computers; incorporating:
   - High performance A/D conversion for recording and signal processing (e.g., 16 bits-5 MHz; 8 bits-500 MHz) (D-6)
   - Automatic generation of software from "natural language" (E-1)
   - Very fast, small, inexpensive read-and-write memories (E-5)
   - Highly parallel architecture based on systolic chips (E-6)
   - Computer language which is really appropriate for parallel processing (E-7)
   - Ability to deal with large masses of data from many (10^4) sensor locations in a highly cluttered non-stationary environment, as in a distributed system (E-8)
   - Computational methods using numerical and symbolic data (E-11)
   - Totally automated "silicon compilers" (E-12)
   - High-speed computers--parallel and array processors in compact portable modules (i.e., desk-top Crays) (E-13)
   - Molecular-scale electronic circuit elements and conductors (G-3)
   - 3-D logic and memory circuits in single material (G-10)
   - Optical read/write recording devices (G-19)
2. Advanced sensor development; incorporating:
   - Sub-wavelength optical imaging by gradient techniques (J-2)
   - Integrated sensors on an electronic chip for measurement of pressure, temperature, acceleration (G-2)
   - NMR imaging for investigation of structural and mechanical properties of composite materials (K-1)
   - Integrated optical sensors/digital processing elements in a single chip focal plane array (G-4)
   - Infrared detector arrays at several frequency bands on a single chip with fast readout (G-21)
   - High density, two-dimensional, solid state arrays for imaging in the visible and infrared (G-24)
   - Nd: YAG lasers with average power > 1 kw, for manufacturing (J-9)
   - Optical fiber sensors for measurement of physical parameters (J-3)
   - Optical fiber sensors for measurement of chemical properties (J-4)
   - Real-time holographic interferometry through fiber optics (J-5)
   - Acoustic imaging for reconnaissance of the interiors of structures and non-destructive testing (K-3)

Manufacturing (cont.)

"A" list (cont.):

3. New/improved military capabilities based upon "intelligent processing" concepts; incorporating:
   - Graphite oxidation and inhibition studies for the development of high-temperature materials with excellent characteristics of corrosion-resistant surfaces (C-14)
   - Realistic 3-D models of physical phenomena (fluid flow, properties of materials) using supercomputers (E-17)
   - Electrodeposition processes to produce materials for ICs efficiently and economically (G-9)
   - Bulk crystal growth Ga:As and III-V's and alloys (G-12)
   - Heterostructure superlattices of layered materials (G-14)
   - Rapid solidification processing of high strength materials (I-7)
   - High-energy laser welding of structure or structural components (I-8)
   - Chemical approaches to formation of high purity, crack resistant ceramics (I-20)

4. Autonomous machine vision/image recognition; incorporating:
   - Automated image recognition and classification through use of AI techniques (L-1)
   - Vision for robotic systems (L-2)

5. Man-machine interactions; incorporating:
   - Optimum allocation of decisions and actions between humans and machines in a man-machine system (L-4)
   - CAD/CAM-type systems with prediction models of human performance for design of human interfaces to large-scale systems (L-19)
   - Man-machine mutual monitoring loops (L-20)

6. Manufacturing systems integration to enable factory of the future to be a viable concept (L-16)

7. Processing of limited/non-error-free data sets; incorporating:
   - Optimum adaptive processing of limitied and/or non-error-free data sets (e.g., time limited outputs of real arrays of sensors) (D-2)
   - Threshold logic for decision making in situations of incomplete information (L-17)

8. Decision support system for manufacturing decision making (e.g., for efficient task assignment and efficient procurement procedures) (revision of L-18)

9. "Muscle-like" mechanical actuators (L-21)

Manufacturing (cont.)

"B" list

1. Automatic understanding of speech of a specific individual (L-6)
2. Automated chemical analysis using robotics, for laboratory or manufacturing plant (L-8)
3. Artificial intelligence applications in manufacturing (new topic)
4. Precision engineering (new topic)

Manufacturing

"C" list:

1. Biosensors based on neuro-receptors for imparting specificity (A-11)
2. Use of biotechnology (chemicals and "intelligent" bacteria) as an aid to micro-electronics production (A-12)
3. Laser synthesis of energetic molecules (B-3)
4. Nonintrusive measurement techniques for multiphase chemical reacting flows (B-8)
5. Accurate quantum mechanical calculations of the barriers to chemical reactions (B-11)
6. Coherent signal processing systems for active/passive spatially dispersed sets of sensors (D-7)
7. Hardware-software interfaces for computational techniques for control, stabilization and identification of large distributed parameter systems--specifically use of parallel architectures in these problems (E-18)
8. Design principles for substantially improved reliability of electronic systems (G-17)
9. Fiber-reinforced ceramics for high-strength applications at high temperatures (I-3)
10. Metal matrix composites for high strength-to-weight [illegible]-6)
11. CO_2 lasers for manufacturing with power > 10 kw (J-1[illegible])
12. Development and demonstration of design principles for substantially improved reliability of weapons systems (L-9)
13. Automated diagnostics systems predicting the nature of failures in complex systems such as nuclear power plants (L-12)
14. Remote computer-control of animal behavior--alternate to mechanical robots (L-15)
15. Electrorheological fluid actuators (L-22)

Mission Support - Biomedical Technologies

"A" list:

1. Targeted delivery and sustained release of materials; incorporating:
   - Drugs effectively targeted against specific cell types (e.g., cancer cells) with sustained release (A-4)
2. Development of organisms that metabolize militarily relevant products (revision of A-5)
3. Development of organisms that will counter the biodegradation of structures (A-6)
4. Decontamination of personnel and equipment exposed to CBW agents; incorporating:
   - System for detoxification of personnel and equipment exposed to biological and chemical agents without harm to personnel (A-10)
5. Prophylactic/therapeutic compounds for CBW agents; incorporating:
   - "Vaccine" against chemical warfare and radiation effects (even if only short-term) (A-14)
6. Biologically based materials separation techniques (new topic - group A)
7. Bioprocess technology for materials (new topic - group A)

"B" list:

1. Blood surrogates for universal transfusability, competitive with natural product (A-1); and, replacement oxygen carrier fluid
2. Materials for control of human immune response in treatment of diseases of military importance (A-3)
3. Biosensors for imparting specificity (A-11)
4. Bio-catalysis with immobilized enzymes (B-5)
5. Enzyme catalysts that work in non-aqueous environments (B-9)
6. Artificial skin development (new topic - group A)
7. Rapid identification of chemical agents; incorporating:
   - System for detoxification of personnel and equipment exposed to biological and chemical agents without harm to personnel (A-10)

Mission Support - Human Factors

"A" list:

1. Intelligent computer-aided instruction
(new topic)

2. Decision aiding systems;
incorporating:
- Threshold logic for decision making in situations of incomplete information (L-17)
- Decision support system for military decision making (e.g., for efficient task assignment and efficient procurement procedures (L-18)

3. Image generation/display
(new topic)

4. Cognitive abilities/aptitude measurement and performance prediction/assessment
(new topic)

"B" list:

1. Embedded systems for training and job aiding
(new topic)

2. Computer-aided design (CAD) for optimized man-machine interfaces and system manpower, personnel and training
(new topic)

3. Combat environment simulation technology
(new topic)

4. Sensing, control and manipulator technologies for remote/robotic devices;
incorporating:
- Automated image recognition and classification through use of AI techniques (L-1)
- Vision for robotic systems (L-2)
- Automatic understanding of speech of a specific individual (L-6)
- Automatic understanding of speech of a general class of individuals (L-7)

Mission Support

"C" List:

1. Completely closed life support systems (A-8)
2. Protective compounds to minimize physiologic damage caused by radiation (A-9)
3. Use of biotechnology (chemical and "intelligent" bacteria) as an aid to microelectronics production (A-12)
4. Computer analysis of large molecules (viruses, etc.) (A-18)
5. Pharmacological enhancement of performance using circadian phase-resetting drugs (A-21)
6. Enhancement of alertness on duty by circadian scheduling of naps and sleep periods (A-23)
7. Development of single integrated "all-weather" visual displays for use by aircraft operator (D-1)
8. Optimum allocation of decisions and actions between humans and machines in a man-machine system (L-4)
9. Remotely operated unmanned weapon systems (L-14)
10. CAD/CAM-type systems with prediction models of human performance for design of human interfaces to large-scale systems (L-19)

Mobility

"A" list:

1. Adiabatic diesel engines and related technology;
   incorporating:
   - Spark-ignited diesel engines, permitting use of a wide spectrum of fuels (C-2)
   - Near-adiabatic diesel engines utilizing high-temperature ceramic components (and no circulating coolant) (C-3)
   - Stable high-temperature lubricants for near-adiabatic diesel engines (C-10)
2. Engines with low IR signatures;
   incorporating:
   - Aircraft engines with low infrared emissions (C-9)
3. Fuel cells for vehicle propulsion;
   incorporating:
   - Efficient, inexpensive fuel cells (C-18)
4. Reduced observables;
   incorporating:
   - Materials with reduced radar and IR signatures (D-14)
5. Active control of sound;
   incorporating:
   - Active control of radiated sound (D-18)
   - Active control of reflected sound (target strength) (D-19)
6. High temperature non-metallic materials - application of novel processing methods and science;
   incorporating:
   - Fiber-reinforced ceramics for high-strength applications at high temperatures (I-3)
   - Novel methods of preparation of large single or polycrystalline materials, usually prepared as ceramics, such as SiC, AlN, etc. (I-9)
   - Practice of attainment of high temperature ceramics that are tough, durable and impact resistant (I-12)
   - Inorganic polymer systems for high temperature structural applications (I-16)
   - Oxidation resistant lightweight composites for performance above 3000° F (I-17)
   - Chemical approaches to formation of high purity, crack resistant ceramics (I-20)
7. Automated vision systems;
   incorporating:
   - Automated image recognition and classification through use of AI techniques (L-1)
   - Vision for robotic systems (L-2)
8. Man-machine interface;
   incorporating:
   - Optimum allocation of decisions and actions between humans and machines in a man-machine system (L-4)
   - Man-machine mutual monitoring loops (L-20)

"A" list (cont.):

9. Automated speech understanding;
   incorporating:
   - Automatic understanding of speech of a specific individual (L-6)
   - Automatic understanding of speech of a general class of individuals (L-7)

10. Robotic task manipulators for mobility systems;
    incorporating:
    - Unmanned orbiting robotics vehicles for spacecraft repair and upgrade (L-13)

11. Control of vortex flow for both air and underwater applications;
    incorporating:
    - Utilization of large flow structure for ultramaneuverable vehicles in air and under water (H-2)
    - Vortex trapping/dynamic lift enhancement (H-9)

12. Supersonic combustion for high mach number air breathing propulsion (H-4)

"B" list:

1.* Alkali metal/halogen combustion systems for closed power production in space and under water (C-6)

2.* Metal slurry propellants for high volumetric energy density air breathing fuels (C-15)

3.* High power density/lightweight batteries;
incorporating:
- Long lived batteries for space applications (C-16)
- High power, high energy density batteries (C-17)

4.* Hardware-software interfaces for computational techniques for control, stabilization and identification of large distributed parameters systems--specifically use of parallel architectures in these problems (E-18)

5.* Practical application of ion implantation and/or high energy laser irradiation to produce hard, wear- and corrosion-resistant surfaces (I-5)

6.* Underwater drag reduction via boundary layer control or modification (H-1), and Laminar-flow-control winged aircraft (LFC) for economy, range, and control increase (H-14)

7.* Corona glow discharge chemical/biological decon systems (new topic)

* No protocol submitted

Mobility

"C" list:

1. Elimination of soot formation in military engines (C-1)
2. Techniques for producing synthetic aircraft fuels (C-5)
3. Gas turbine engines capable of burning available fuel (liquid, solid or gaseous) (C-8)
4. Non-thrust propulsion system (C-13)
5. Graphite oxidation and inhibition studies for the development of high-temperature materials with excellent characteristics of corrosion-resistant surfaces (C-14)
6. Development of single integrated "all-weather" visual displays for use by aircraft operator (D-1)
7. Active control of radar cross sections (D-13)
8. Antennas with low radar cross sections (D-15)
9. Air vehicles with very low observable signatures through multidisciplinary technology integration (D-16)
10. Realistic 3-D models of physical phenomena (fluid flow, properties of materials) using supercomputers (E-17)
11. Hardware and software for the computation of full 3-D viscous fluid flow around complex flight structure (H-7)
12. Attainment of supersonic flight which is economically competitive with present subsonic transports (H-15)
13. High-permeability rare earth permanent magnet systems for low-cost rotating machinery, accelerators, etc. ((I-2)
14. Bonding of surfaces by high energy and chemical alteration (I-11)
15. Tailoring of filamentary composite structures for aircraft and other vehicles to avoid instabilities (dynamic) and improve response (I-13)
16. Lightweight (density < 2 g/cm^3) composite materials for space application--radiation, vacuum resistant (I-15)
17. Surface coating non-sticking for water and ice to prevent fogging and make de-icing unnecessary (I-19)
18. Optical fiber sensors for measurement of physical parameters (J-3)
19. Acoustic imaging for reconnaissance of the interiors of structures and non-destructive testing (K-3)
20. Development and demonstration of design principles for substantially improved reliability of weapons systems (L-9)
21. Automated diagnostics systems predicting the nature of failures in complex systems such as nuclear power plants (L-12)

Search and Surveillance

"A" list:

1. High performance A/D conversion for recording and signal processing (e.g., 16 bits-5 MHz; 8 bits-500 MHz) (D-6)
2. Technologies associated with reduced signatures military platforms; incorporating:
   - Materials with reduced radar and IR signatures (D-14)
   - Antennas with low radar cross sections (D-15)
   - Air vehicles with very low observable signatures through multidisciplinary technology integration (D-16)
3. Integrated optical sensors/analog/digital processing elements in a single chip focal plane array (G-4)
4. Image recognition and AI; incorporating:
   - Automated image recognition and classification through use of AI techniques (L-1)
   - Threshold logic for decision making in situations of incomplete information (L-17)
5.* Growth of 3- and 4-components compound semiconductors of desired (specified) characteristics (G-6)
6. Framework for modular signal processors; incorporating:
   - Automatic mapping of signal processing algorithms described in high level language onto specific multiprocessor architecture or VLSI configurations (D-3)
   - Computer language which is really appropriate for parallel processing (E-7)
   - Realistic 3-D models of physical phenomena (fluid flow, properties of materials) using supercomputers (E-17)
7. Multi-signature decoys (including visual holograms) (D-12)
8. Active control of sound; incorporating:
   - Active control of radiated sound (D-18)
   - Active control of reflected sound (target strength) (D-19)
9. Melding of best features of digital and analog computing, including optical processing, to get extremely high computation rates, with appropriate dynamic range, on many parallel channels (E-14)
10. Heterostructure superlattices of layered materials (G-14)
11. High density, two-dimensional, solid state arrays for imaging in the visible and infrared (G-24)

* No protocol submitted

"A" list (cont.):

12. Optical fiber technology;
incorporating:
- Ultra low-loss fiber optics (J-1)
- Optical fiber sensors for measurement of physical parameters (J-3)

13. Optimum allocation of decisions and actions between humans and machines in a man-machine system (L-4);
also related to:
- Man-machine mutual monitoring loops (L-20)
- Sensors for monitoring changes in human alertness and vigilance (A-20)

14.* Highly parallel architecture based on systolic chips (E-6)

15. Monolithic GaAs and III-V related components
(new topic)

16. Fast-wave amplifiers as efficient high power sources of coherent millimeter and sub-millimeter wave radiation
(new topic)

17. Low-probability-of-intercept (LPI) and long range air frame classification radar for airborne intercept
(new topic)

18. Chemical bonding agents
(new topic)

19. High speed computers--parallel and array processors in compact portable modules (i.e., desk-top Crays) (E-13)

* No protocol submitted

"B" list:

1. High power, compact mm wave antennas with distributed sources (D-4)
2. High power narrow-width pulse;
   incorporating:
   - Pico-second pulse compression for high power spikes and counter stealthy (D-20)
3. Improved reliability of electronic systems;
   incorporating:
   - Development and demonstration of design principles for substantially improved reliability of weapons systems (L-9)
4.* Optimum adaptive processing of limited and/or non-error-free data sets (e.g., time limited outputs of real arrays of sensors) (D-2)
5.* Active control of radar cross sections (D-13)
6.* Computational methods using numerical and symbolic data (E-11)
7.* Realistic 3-D models of physical phenomena (fluid flow, properties of materials) using supercomputers (E-17)
8.* Laser phased arrays for laser power scaling for high brightness (F-10)
9.* Synthetic nonlinear optics materials custom-designed for specific applications (e.g., optical computer elements) (G-1)
10.* Semiconductor device development utilizing bandgap engineering (G-7)
11.* Coherent submillimeter wave source in the solid state (G-8)
12.* Macroelectronic arrays (e.g., Flat panel displays, electronic tablets) (G-11)
13.* Bulk crystal growth Ga:As and III-V's and alloys (G-12)
14.* Design principles for substantially improved reliability of electronic systems (G-17)
15.* Infrared detector arrays at several frequency bands on a single chip with fast readout (G-21)
16.* Conducting polymers for "all-plastic" batteries and lightweight electronics (I-1)
17.* High-permeability rare earth permanent magnet systems for low-cost rotating machinery, accelerators, etc. (I-2)
18.* Metal matrix composites for high strength-to-weight (I-6)
19.* Optical fiber sensors for measurement of physical parameters (J-3)
20.* Autonomous weapons vision with automatic target recognition (L-3)
21. Blocked impurity band detectors for low background long wave infrared based on:
   - Shottky barrier-type IR detectors (G-22)

* No protocol submitted

Search and Surveillance

"C" list:

1. Aircraft engines with low infrared emissions (C-9)
2. Low noise mm wave receivers (D-5)
3. Coherent signal processing systems for active/passive spatially dispersed sets of sensors (D-7)
4. Automatic generation of software from "natural language" (E-1)
5. Parallel processing based on optical communication between N processors and M memories (not necessarily chip-to-chip optical interconnections) (E-2)
6. Parallel processing based on novel interconnect hard wired (non-optical) schemes (e.g., "cosmic cube" architecture) (E-3)
7. Architecture based on neuron connectivity in mammalian brains (E-4)
8. Very fast, small, inexpensive read-and-write memories (E-5)
9. Ability to deal with large masses of data from many (10^4) sensor locations in a highly cluttered non-stationary environment, as in a distributed system (E-8)
10. Methods of in-putting (with regulation) power and removing heat from large computer systems which have cycle times <2 nanoseconds (E-9)
11. High-speed computers--parallel and array processors in compact portable modules (i.e., desk-top Crays) (E-13)
12. Array detectors and radiator to replace mechanically moving disk and tape recording devices (E-15)
13. Molecular-scale electronic circuit elements and conductors (G-3)
14. 3-D logic and memory circuits in signal material (G-10)
15. Exploratory III-V Heterojunction High Speed Devices (G-13)
16. Three terminal solid state devices operating above 100 GHz (3 mm) for radars, communications (G-18)
17. Optical read/write recording devices (G-19)
18. Shottky barrier-type IR detectors (G-22)
19. Sub-wavelength optical imaging by gradient techniques (J-2)
20. Inexpensive and precise large optical systems (J-13)
21. Acoustic imaging for reconnaissance of the interiors of structures and non-destructive testing (K-3)
22. Active/passive multi-spectral scanners with automated terrain feature classification (K-6)

"C" list (cont.):

23. Acoustic imaging arrays for antisubmarine warfare (K-7)
24. Smart buoys for environmental monitoring and surveillance (K-10)
25. Combined radar, radiometer and lidar profile of atmospheric wind, temperature and humidity for use in short- and medium-term weather forecasts (K-19)
26. Automated diagnostics systems predicting the nature of failures in complex systems such as nuclear power plants (L-12)
27. Unmanned orbiting robotics vehicles for spacecraft repair and upgrade (L-13)
28. Remotely operated unmanned weapon systems (L-14)
29. Decision support system for military decision making (e.g., for efficient task assignment and efficient procurement procedures) (L-18)

LIST OF ETS CHOSEN BY SESSION CHAIRMEN/CHOSEN AT WORKSHOP

(By Technical Area)

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - BIOTECHNOLOGY, MEDICINE AND LIFE SCIENCES (A)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	SBS/EW	C^3	
A ✓						1. Blood surrogates for universal transfusability, competitive with natural product
						2. Therapeutic materials incorporating neurotransmitters for improving human behavior and performance
A ✓						3. Therapeutic materials for control of human immune response in treatment of diseases of military importance
A						4. Drugs effectively targeted against specific cell types (e.g., cancer cells) with sustained release
A ✓						5. Development of organisms that will metabolize toxic waste products
A ✓						6. Development of organisms that will counter the biodegradation of structures
						7. Development of design rules and engineering principle for synthesis of proteins with desired properties
✓						8. Completely closed life support systems
✓						9. Protective compounds to minimize physiologic damage caused by radiation
A ✓					✓	10. System for detoxification of personnel and equipment exposed to biological and chemical agents without harm to personnel
A ✓	✓					11. Biosensors based on neuro-receptors for imparting specificity
✓	✓					12. Use of biotechnology (chemicals and "intelligent" bacteria) as an aid to micro-electronics production
					✓	13. Multipurpose detoxifying agent against chemical warfare
A						14. "Vaccine" against chemical warfare and radiation effects (even if only short-term)
						15. Salt water crops
						16. Control of biological aging
						17. Automatic discovery of vaccines, diseases, etc. through computer models of living molecules
✓						18. Computer analysis of large molecules (viruses, etc.)
						19. Detection and modification of automatic behavior syndrome
				A	✓B	20. Sensors for monitoring changes in human alertness and vigilance
✓						21. Pharmacological enhancement of performance using circadian phase-resetting drugs
						22. Mathematical models for designing biocompatible duty-rest schedules for round-the-clock operations
✓					✓	23. Enhancement of alertness on duty by circadian scheduling of naps and sleep period

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - CHEMISTRY AND CATALYSIS (B)

Mis.Sup.	Mafg.	Mobil.	Dir.En.	S&S/EM	C^3	
						1. Physical separation of gases or liquids by means of hollow fibers or affinity chromatography
						2. Use of thermite combustion reactions to make high temperature materials
	✓					3. Laser synthesis of energetic molecules
						4. Methanol production from atmospheric CO_2 using solar energy
A						5. Bio-catalysis with immobilized enzymes
						6. Compound synthesis by solar photo-electrochemistry
						7. $Al + H_2O \rightarrow H_2 + Al_2O_3$ + Heat (Recycle energy economy)
	✓					8. Nonintrusive measurement techniques for multiphase chemical reacting flows
A						9. Enzyme catalysts that work in non-aqueous environments
						10. Molecular-level understanding of heterogeneous catalysis
	✓					11. Accurate quantum mechanical calculations of the barriers to chemical reactions
						12. Use of polymers to control solution properties

EMERGING TECHNOLOGIES - COMBUSTION, PROPULSION, AND ENERGY (C)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	
		✓				1. Elimination of soot formation in military engines
		A				2. Spark-ignited diesel engines, permitting use of a wide spectrum of fuels
		A ✓				3. Near-adiabatic diesel engines utilizing high-temperature ceramic components (and no circulating coolant)
						4. Miniaturized RTGs
		✓				5. Techniques for producing synthetic aircraft fuels
		B ✓				6. Alkali metal/halogen combustion systems for closed power production in space and under water
						7. Dynamic feedback concepts for control of combustion instability in air breathing and rocket propulsion
		✓				8. Gas turbine engines capable of burning available fuel (liquid, solid or gaseous)
		A ✓		✓		9. Aircraft engines with low infrared emissions
		A ✓				10. Stable high-temperature lubricants for near-adiabatic diesel engines
						11. High-performance solid fuel ramjet (ducted solid rocket)
						12. Liquid propellant guns
		✓				13. Non-thrust propulsion system
	A ✓	✓				14. Graphite oxidation and inhibition studies for the development of high-temperature materials with excellent characteristics of corrosion-resistant surfaces
		B ✓				15. Metal slurry propellants for high volumetric energy density air breathing fuels
		B			✓A	16. Long lived batteries for space applications
		B ✓			✓A	17. High power, high energy density batteries
		A			✓	18. Efficient, inexpensive fuel cells
					✓B	19. Efficient, inexpensive photovoltaic cells

EMERGING TECHNOLOGIES - COMMUNICATIONS, RADAR AND SIGNAL PROCESSING

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	
✓		✓			✓	1. Development of single integrated "all-weather" visual displays for use by aircraft operator
	A✓			B	✓	2. Optimum adaptive processing of limited and/or non-error-free data sets (e.g. time limited outputs of real arrays of sensors)
				A✓	✓A	3. Automatic mapping of signal processing algorithms described in high level language onto specific multiprocessor architecture or VLSI configurations
				B✓	✓A	4. High power, compact mm wave antennas with distributed sources
				✓	✓B	5. Low noise mm wave receivers
	A✓			A	✓A	6. High performance A/D conversion for recording and signal processing (e.g., 16 bits-5MHz; 8 bits-500MHz)
	✓			✓	✓	7. Coherent signal processing systems for active/passive spatially dispersed sets of sensors
					✓A	8. Distributed automatic control of a communications network and link parameters in a hostile environment
					✓B	9. Two-way address selectable, fiber optic video/phone/data networks
					✓	10. High power spaceborne ULF transmitters for submarine communications
					✓	11. Low cost, high speed A-D/D-A with built-in filtering
				A✓		12. Multi-signature decoys (including visual holograms)
		✓		B		13. Active control of radar cross sections
		A✓		A✓	✓	14. Materials with reduced radar and IR signatures
		✓		A✓	✓	15. Antennas with low radar cross sections
		✓		A	✓	16. Air vehicles with very low observable signatures through multidisciplinary technology integration
						17. Determination of dielectric properties of targets from inverse scattering methods
		A✓		A✓		18. Active control of radiated sound
		A✓		A		19. Active control of reflected sound (target strength)
				B		20. Pico-second pulse compression for high power spikes and counter stealth

EMERGING TECHNOLOGIES - COMPUTERS (E)

Mis.Sup.	Mafg.	Mobil.	Dir.En.	S&S/EW	C^3	
	A✓			✓	✓A	1. Automatic generation of software from "natural language"
				✓	A	2. Parallel processing based on optical communication between N processors and M memories (not necessarily chip-to-chip optical interconnections)
				✓	✓A	3. Parallel processing based on novel interconnect hard wired (non-optical) schemes (e.g., "cosmic cube" architecture)
				✓	✓	4. Architecture based on neuron connectivity in mammalian brains
	A✓			✓	✓	5. Very fast, small, inexpensive read-and-write memories
	A✓			A✓	✓A	6. Highly parallel architecture based on systolic chips
	A✓			A✓	✓A	7. Computer language which is really appropriate for parallel processing
	A✓			✓	✓A	8. Ability to deal with large masses of data from many (10^4) sensor locations in a highly cluttered non-stationary environment, as in a distributed system
				✓		9. Methods of in-putting (with regulation) power and removing heat from large computer systems which have cycle times <2 nanoseconds
						10. Squid supercomputers
	A✓			B✓	✓B	11. Computational methods using numerical and symbolic data
	A✓				✓B	12. Totally automated "silicon compilers"
	A✓			✓	✓B	13. High-speed computers--parallel and array processors in compact portable modules (i.e., desk-top Crays)
				A✓		14. Molding of best features of digital and analog computing, including optical processing, to get extremely high computation rates, with appropriate dynamic range, on many parallel channels
				✓	✓	15. Array detectors and radiator to replace mechanically moving disk and tape recording devices
					✓	16. High performance numerical algorithms for stiff, singular, or discontinuous problems
	A✓	✓		A		17. Realistic 3-D models of physical phenomena (fluid flow, properties of materials) using supercomputers
	✓	B✓			✓B	18. Hardware-software interfaces for computational techniques for control, stabilization and identification of large distributed parameter systems--specifically use of parallel architectures in these problems

EMERGING TECHNOLOGIES - DIRECTED ENERGY RELATED TECHNOLOGY F

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	
			A			1. High-current radiofrequency quadrupole accelerators
						2. Reusable opening switches for very high power (10^{10} - 10^{12}w), high voltage (~ ...), ~ nsec rise times
			A			3. High-current, low-emittance ion sources for tritium and lithium beams
			A			4. Negative ion (e.g., hydrogen) beam neutralization using lasers for photodetachment
						5. Light-weight non-nuclear space power sources in 5-50 MW power regime
						6. Laser-guided charged particle beam propagation in the atmosphere
						7. DEW concepts using anti-matter beams
						8. High-voltage insulators for pulsed application in space
			B			9. Coupled resonators for laser power scaling to high brightness
			B	B		10. Laser phased arrays for laser power scaling for high brightness
						11. Large deformable optics
						12. Wavefront sensors (return and outgoing)
						13. Cooled aperture sharing elements
			B✓			14. Non linear phase conjugation techniques
						15. Cooled deformable optics
						16. High current density, high speed, current collectors
						17. Advanced materials per higher stiffness-to-mass, erosion resistance and higher magnetic saturation flux density for E. M. propulsion devices
						18. Very high bandwidth, agile laser radars for E. M. gun targeting
			B✓			19. High efficiency, high power free electron lasers in the near-IR or visible
						20. Very precise, short time constant attitude control systems for large spacecraft

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - ELECTRONIC MATERIALS AND DEVICES (G)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	Item
				B✓		1. Synthetic nonlinear optics materials custom-designed for specific applications (e.g., optical computer elements)
	A✓					2. Integrated sensors on an electronic chip for measurement of pressure, temperature, acceleration
	A✓			✓	B	3. Molecular scale electronic circuit elements and conductors
	A✓			A✓	B	4. Integrated optical sensors/digital processing elements in a single chip focal plane array
						5. Synchrotron radiation source X-ray lithography
				A✓	✓	6. Growth of 3 and 4 components compound semiconductors of desired (specified) characteristics
				B✓	B	7. Semiconductor device development utilizing bandgap engineering
				B✓	✓	8. Coherent submillimeter wave source in the solid state
	A				✓	9. Electrodeposition processes to produce materials for ICs efficiently and economically
	A✓			✓		10. 3-D logic and memory circuits in single material
				B✓	B	11. Macroelectronic arrays (e.g., Flat panel displays, electronic tablets)
	A			B✓		12. Bulk crystal growth Ga:As and III-V's and alloys
				✓		13. Exploratory III-V Heterojunction High Speed Devices
	A			A✓		14. Heterostructure superlattices of layered materials
					✓	15. Elimination of cosmic ray interferences in microchips
						16. Superconductive computer technology (more general than Josephson, as previously practiced at IBM)
	✓			B	✓A	17. Design principles for substantially improved reliability of electronic systems
				✓	✓	18. Three terminal solid state devices operating above 100 GHz (3 mm) for radars, communications
	A✓			✓	✓B	19. Optical read/write recording devices
					✓	20. Commercial production for Ga:As and other semiconducting materials in space
	A✓			B✓		21. Infrared detector arrays at several frequency bands on a single chip with fast readout
				✓		22. Shottky barrier-type IR detectors
						23. High sensitivity photodetectors utilizing surface excitation enhancement
	A✓			A✓		24. High density, two-dimensional, solid state arrays for imaging in the visible and infrared
					✓	25. High efficiency solar cells for space applications, especially III-V materials

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - FLUID DYNAMICS (H)

Mis.Sup.	Mafg.	Mobil.	Dir.En.	S&S/EW	C^3	
		B ✓				1. Underwater drag reduction via boundary layer control or modification
		A ✓				2. Utilization of large flow structure for ultramaneuverable vehicles in air and under water
						3. Acoustic and flow structure concepts to promote fine atomization and mixing
		A ✓				4. Supersonic combustion for high mach number air breathing propulsion
						5. Numerical solution of fluid equations of motion so as practically to predict flows with large volumes of turbulence
						6. Techniques for control of surfaces inflows (control and computational fluid dynamics)
		✓				7. Hardware and software for the computation of full 3-D viscous fluid flow around complex flight structure
						8. Geometrical control of turbulent jet mixing for improved combustion
		A ✓				9. Vortex trapping/dynamic lift enhancement
						10. Dynamic "thrust" through active aeroelastic control (aircraft drag reduction)
						11. Material transport in vacuum via droplet stream
						12. Adaptive supercritical airfoil design
						13. Off design performance of low Reynolds number flight in sea surface environment
		B				14. Laminar-flow-control winged aircraft (LFC) for economy, range, and control increase
		✓				15. Attainment of supersonic flight which is economically competitive with present subsonic transports

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - MACROSCOPIC MATERIALS (1)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EM	C^3	Technology
				B	✓A	1. Conducting polymers for "all-plastic" batteries and lightweight electronics
		✓		B		2. High-permeability rare earth permanent magnet systems for low-cost rotating machinery, accelerators, etc.
	✓	A ✓				3. Fiber-reinforced ceramics for high-strength applications at high temperatures
						4. Development of fundamental understanding of materials surface preparation, including interface physics and chemistry on the atomic scale
		B				5. Practical application of ion implantation and/or high energy laser irradiation to produce hard, wear and corrosion-resistant surfaces
	✓		A	B		6. Metal matrix composites for high strength-to-weight
	A					7. Rapid solidification processing of high strength materials
	A ✓					8. High-energy laser welding of structure or structural components
		A				9. Novel methods of preparation of large single or polycrystalline materials, usually prepared as ceramics, such as SiC, AlN, etc.
						10. Manufacturable superconductors with transition temperatures >30-40 K
		✓				11. Bonding of surfaces by high energy and chemical alteration
		A ✓				12. Practice of attainment of high temperature ceramics that are tough, durable and impact resistant
		✓				13. Tailoring of filamentary composite structures for aircraft and other vehicles to avoid instabilities (dynamic) and improve response
						14. Mechanics and materials for wear resistance under cryogenic conditions
		✓			✓	15. Lightweight (density < 2 g/cm^3) composite materials for space application--radiation, vacuum resistant
		A				16. Inorganic polymer systems for high temperature structural applications
		A ✓				17. Oxidation resistant lightweight composites for performance above 3000° F
						18. Very high temperature, low-loss dielectric window materials
		✓			✓	19. Surface coating non-sticking for water and ice to prevent fogging and make de-icing unnecessary
	A	A ✓				20. Chemical approaches to formation of high purity, crack resistant ceramics
						21. Mineral carriers for nuclear waste elements (Zn-Gd) that are impervious to long-term radiation effects
						22. Electrodeposition processes enabling the production of refractory metal coating at room temperatures in aqueous solutions
						23. Fundamental understanding of the role of alloying elements in producing surfaces resistant to localized corrosion
					✓	24. Space based system for fabrication of components for space structures
						25. Application of ceramic and advanced composites to guns

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - OPTICS AND LASERS (J)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	
				A	√A	1. Ultra low-loss fiber optics
	A√			√		2. Sub-wavelength optical imaging by gradient techniques
	A√	√		A		3. Optical fiber sensors for measurement of physical parameters
	A√					4. Optical fiber sensors for measurement of chemical properties
	A√					5. Real-time holographic interferometry through fiber optics
			B			6. Coherent gamma-ray sources (e.g., X-ray lasers)
					√B	7. Steerable laser diode arrays at powers of approx. 1 kw/cm^2
						8. Rare-gas halid excimer lasers with high efficiency and high energy output
	A√					9. Nd: YAG lasers with average power > 1 kw, for manufacturing
	√					10. CO_2 lasers for manufacturing with power > 10 kw
						11. Mid- and far-infrared optical fibers of low-loss
					√B	12. Satellite laser technology for satellite-submarine (submerged) two-wav communications
				√		13. Inexpensive and precise large optical systems

EMERGING TECHNOLOGIES - REMOTE SENSING, OCEANOGRAPHY AND METEOROLOGY (K)

Mis. Sup.	Mafg.	Mobil.	Dir. En.	S&S/EW		
	A ✓					1. NMR imaging for investigation of structural and mechanical properties of composite materials
						2. Airborne/spaceborne laser radars (eye-safe) for remote sensing of global atmospheric properties
	A ✓	✓		✓		3. Acoustic imaging for reconnaissance of the interiors of structures and non-destructive testing
						4. Microwave mapping of wind speed at the sea surface from satellite radar
						5. Doppler weather radar (airborne) for storm and wind tracking and warning
				✓		6. Active/passive multi-spectral scanners with automated terrain feature classification
				✓		7. Acoustic imaging arrays for antisubmarine warfare
					✓	8. Long-range weather forecasting
						9. Sensing of sea state, surface weather, and remote sensing of upper atmosphere from large unmanned ocean buoys
				✓		10. Smart buoys for environmental monitoring and surveillance
						11. Weather forecasting systems that include artificial intelligence linked with remote sensing instruments to continuously update forecasts and that learn from experience
					✓	12. 4-D (space and time) assimilation of remotely sensed meteorological data for incorporation into prediction models
					✓	13. Expansion of environmental forecasting models to accept real-time satellite data for regular forecast verification and condition updates
						14. Use of fully coupled air-ocean-sea ice models for prediction of lead frequencies, orientations and ice thickness distribution for the polar oceans
						15. System for remotely determining sea ice thickness with high resolution and small footprint
						16. Techniques for remote sensing (imaging) of magnetospheric activity
					✓	17. Automated onboard satellite processing of atmospheric and ocean characteristics
						18. Satellite borne altimeters for time variability of ocean surface waves and currents
				✓		19. Combined radar, radiometer and lidar profile of atmospheric wind, temperature and humidity for use in short- and medium-term weather forecasts
						20. Tomographic arrays for mesoscale ocean monitoring and forecasting
						21. Windsat satellite borne CO_2 lidar for measuring global wind fields
						22. Spaceborne optical and radar systems for global monitoring of CO_2 and hydrologic cycles
						23. Aircraft sounding system with fast response instruments aboard new generation aircraft and automatic readout via radio. The weather service could get a detailed verticle sounding of the atmosphere whenever a takeoff or landing occurs. Useful from land or ship (carriers).
					✓	24. Global measurements of magnetospheric electrical circuit for better predictions of geomagnetic storms and their effects on space systems
						25. Remote mapping of domestic strategic metal deposits

PARTIAL DELPHI SURVEY RESPONSES - WORKING PAPER

EMERGING TECHNOLOGIES - ROBOTICS, AUTOMATION AND MACHINE INTELLIGENCE (L)

Mis. Sur.	Mafg.	Mobil.	Dir. En.	S&S/EW	C^3	
B✓	A✓	A✓		A✓	✓A	1. Automated image recognition and classification through use of AI techniques
B✓	A✓	A✓				2. Vision for robotic systems
				B✓	✓	3. Autonomous weapons vision with automatic target recognition
✓	A✓	A✓		A✓	✓A	4. Optimum allocation of decisions and actions between humans and machines in a man-machine system
B	B✓	A✓			✓A	6. Automatic understanding of speech of a specific individual
B	✓	A			✓A	7. Automatic understanding of speech of a general class of individuals
	B✓				B	8. Automated chemical analysis using robotics, for laboratory or manufacturing plants
	✓	✓		B		9. Development and demonstration of design principles for substantially improved reliability of weapons systems
					B	10. Development of unmanned, remotely addressable under water vehicles
						11. Unmanned fighter aircraft
	✓	✓		✓		12. Automated diagnostics systems predicting the nature of failures in complex systems such as nuclear power plants
		A✓		✓	✓	13. Unmanned orbiting robotics vehicles for spacecraft repair and upgrade
✓				✓		14. Remotely operated unmanned weapon systems
	✓					15. Remote computer-control of animal behavior--alternate to mechanical robots
	A✓					16. Manufacturing systems integration to enable factory of the future to be a viable concept
A✓	A✓			A✓	✓A	17. Threshold logic for decision making in situations of incomplete information
A✓	A✓			✓	✓A	18. Decision support system for military decision making (e.g., for efficient task assignment and efficient procurement procedures)
✓	A✓					19. CAD/CAM-type systems with prediction models of human performance for design of human interfaces to large-scale systems
	A✓	A✓		A	✓B	20. Man-machine mutual monitoring loops
	A✓					21. "Muscle-like" mechanical actuators
	✓					22. Electrorheological fluid actuators

APPENDIX 12
ET WORKSHOP PROTOCOLS

C³

TECHNOLOGY: Battery Technology (C-16/C-17/I-1)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

C-16/17 as stated - but need to add arctic warfare and undersea surveillance as applications - NiAl, FeAir, FeAg, Li, NiCad, Conducting Polymers are all candidates for various features (eg. low cost, high recharge rate, very low temperature operation).

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Various depending on technology and parameters selected.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

   Some exist, some are emerging (Lithium), some are lab curiosity (polymers)

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

   Don't know.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

   Special military, space or arctic will drive specific features.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

   None specified.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- o Remote unmanned operations (e.g. ice stations for a comm or surveillance)
- o Non-corrosive battery would not release exhaust gases into environment.

B. *To what products or processes might it be applied?*

Satellites, air dropped and sub launched buoys, unmanned and remote electronics, of any type and automatic remote sensors, both military and commercial.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- o Life and operation at low temperatures make some missions possible & certainly more efficient.
- o Lightweight protable equipment; low detectability remote sensors.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Low drain electronics (e.g VHSIC) added to these new batteries will make long term under sea surveillance, arctic warfare, space operations more efficient. (Batteries in space comm haven't been a life limiting component. Lithium on submarines needs special approval.) Two back up pages are provided with special features and problems of each type.

REPORTER: J.B. Hughes

AIDED BY: P.J. Boudreaux

A.R. Lubarsky

BATTERIES CONSIDERED

I IRON AIR

- High and recent technology
- Originally developed for electrical cars
- Secondary type, can be charged again
- Chargeable to 500 times
- High energy, high density battery (3 watt/hrs/kg)
- Low cost/$30.00/kw/hr
- Low weight, weighs 1/5 of the nickel cadmium battery
- Can be mass produced and designed to order

II IRON SILVER BATTERY

- High capacity
- Low life
- Low cost
- Secondary battery, can be re-charged
- Easy to mass produce
- Considered to be standard technology
- Can be designed to specific applications

III LITHIUM BATTERIES

- High-energy batteries
- Some problems still associated with the battery
- Work in extreme temperatures
- Come in different styles
- Many in current routine production stages and are being used in military and commercial applications
- For SDI applications, requires additional development
- Shelf life is 10 years

IV NICKEL CADMIUM BATTERIES

- Not as high energy as lithium
- Does not work in extreme temperatures

V CONDUCTING POLYMERS

- Still a laboratory curiosity
- Shown to work at experimental level
- Funding is running out (ONF funding)
- Have produced only electro-chemical cells and not batteries yet
- High rate
- High energy

VI NICKEL ALUMINUM

- High rate discharge, high energy density
- Primary (cannot be re-charged)
- Has unlimited shelf life
- Rate is greater than 5 amps per square centimeter
- Come in any size
- Reasonable cost
- Space or underwater applications
- Westinghouse Corp. has a production plan currently

TECHNOLOGY: Conductive Polymers for Batteries, Antistatic Packing and Other Applications (C-16/C-17)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Conductive polymers have:

1) low density 0-2 gm/cm^3 depending on processing technique

2) high porosity with small pore diameters suitable for migration of solutes or ions

3) electrical conductivity ranging from 10^{-12} to 10^{2} $(r\text{-}m)^{-1}$ depending on material and dopant (presumed limit is 10^{6} $(r\text{-}m)^{-1}$ equivalent to graphite)

4) varied stability to air exposure depending on the polymers and dopant

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Need aqueous stable doped polymers for many applications; polypyrable and polyphthalocyanine some of best.

2. Processing technology of these materials is a problem

3. Dopants frequently are aggressive chemical species, need find ways of trapping the species permanently when permanent conductivity is desired.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1990-1995 for selected applications in RFI shielding and RAM/RAS

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Low weight, cost and ability to readily incorporate the polymer into other polymeric systems. RFI shielding, RAM/RAS and antistatic packaging likely military drivers. Possible use in electronics packaging and industrial drivers.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975-1980	numerous groups
2. First Experimental Device Application (or first experimental process demonstration) battery	1980	MacDiarmis U. Penn
antistatic	1982	NRL
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Electrical conductor for current transport, signal transport and shielding
Electrical energy storage
X-ray transparent (compared to other materials in which the polymers might be embedded) electrical conductors. (Also possible that these same materials will have semiconductive properties at lower doping, which will provide new radiation detectors).

B. To what products or processes might it be applied?

Batteries
RAM/RAS
RFI, lightening strike shielding via composites
Anti static packaging for electronic devices and precision bearings

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Lower radar cross sections of various platforms
RFI, lighting protection in high strength to weight composites on aircraft

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Ability to vary dielectric constant of matrix material in a composite, coupled with new fiber properties and magnetic materials mixed in, provide new design capabilities for high performance platforms.

REPORTER: Jim Murday

AIDED BY:

C^3

TECHNOLOGY: High Power MM Wave Antenna (D-4)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Antenna Systems

- Lt. wt., high strength parabolic dishes (plastics, epoxy)
- High dielectric prism scanners

Power Sources

- FET devices for electronically scanning arrays
  - thousands of elements per antenna (30% efficiency for heat removal)
  - 10-15 mW output per device (~10 dB gain per device)
- Amplifier/injection locked oscillators to power mech. scanned systems
  - tens of element per antenna (10-20% efficiency)
  - Si (mature): 1-1.2W output/device 5-10 dB gain/device)
  - GaAs (less mature): 1.75-2.0 W output/device
  - InP Gunn Amplifiers: 1 Watt/device (10 dB gain) <stability LNA oper>

Radiating Elements

- Dual frequency, accurately matched (ϕ, amp.) corporate feed structures
  - image enhanced arrays
  - polyrod arrays (high dielectric)

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Computer methods for accurately predicting/modeling performance of mass-produced individual modules
- Simplified module designs amenable to mass production
- Improved material processes for GaAs, InP (production and handling during device development)
- Better thermal management techniques
- Precision machining for corporate feed structures and prisms (mass production milling)
- Develop monolithic element production techniques (improve integration of amps, ϕ-shifters and radiating elements on single substrates)

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

- 2-3 years with appropriate funding
- Power modules sooner than phased array technology

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

No competition

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- MILSTAR /DSCS need for low cost, small size antenna/power systems

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	Phased array	86	NOSC
	Power (PM) modules	84	NOSC
2. First Experimental Device Application (or first experimental process demonstration)	PA	88	NOSC/RADC
	PM	85	NOSC
3. When available for inclusion in product or process?	PA	90-92	RADC
	PM	88	NOSC

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Power amplifiers for EHF transmitters
  - MILSTAR: all Services
  - DSCS
- Satellite cross-link capability
  - military comm.
  - SDI
  - sensor applications
- DCS MM wave transmission

B. *To what products or processes might it be applied?*

- MILSTAR/DSCS terminals
- Advanced space systems
  - SDI
  - sensor applications
- DCS MM wave line of sight transmission

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Substantially reduce the cost and installation impact of EHF Satcom terminals. Smaller size and power requirements allow fielding on larger number of essential but resource limited platforms.

Technology is essential for manpack and high performance aircraft applications.

Provide high bandwidth anti-jam satellite and line of sight MM wave transmission.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Enhanced communications capability for small, mobile force elements → improved unit performance.

Will couple with current VHSIC terminal developments to further reduce size and power requirements for all platforms.

REPORTER: J.B. Hughes

AIDED BY:

C³

TECHNOLOGY: High Performance A/D Conversion for Recording and Signal Processing (D-6/D-11)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

High speed A/D converters for 8, 12, and 16 bits at 1 to 4 Gigasamples per second with bandwidths of 400 MHz and 1 GHz are needed in a monolithic form having power consumptions of less than 5 watts.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Gallium Arsenide, bipolar silicon and Josephson Junction (JJ) superconductive devices are being considered for high speed A/D converters. Microwave packaging and know how are required to implement these digital monolithic designs. Low loss cryogenic coolers having small size are needed for the JJ designs. High Electron Mobility Transistors (HEMT) and Gallium Arsenide appear to be the most promising semiconductor approach. HEMT technology must mature and become BASELINED before production can fully benefit from its properties. DARPA now has a GaAs A/D program underway to develop an 8 bit, 1 Gigasample per sec A/D with a bandwidth of 0 to 350 MHz, and a 4 bit, 3 Gigasample per sec A/D with a bandwidth of 100 Hz to 1 GHz in a monolithic form with target power dissipations of 5.5 watt with a threshold less than 0.25 LSB RMS and an overall S/N ratio of greater than 22 dB for the 3 Gsps device and greater than 46 dB for the 1 Gsps device. The National Bureau of Standards in Boulder, CO is investigating Josephson Junction A/D devices.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Rockwell International is developing a HEMT A/D converter for 10 bits with 200 Megasamples per sec conversion rate at 2 watts. NRL is sponsoring the Honeywell and TRW development of the 1 and 3 Gsps GaAs devices. 5 bit Flash converters have already been built. 1987-88 is the target for the 8 bit devices. The HEMT 10 bit A/DC chip have been built at Rockwell. It contains 6868 transistors, 1379 Schottky diodes, 5118 nodes and 529 resistors.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US HEMT technology is comparable to Japan's and superior to the USSR by at least 5 yrs. Josephson Junction work in the USSR may be comparable to the US A/D work.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Wide bandwidth magnetic recording media has outstripped the capability to electronically record signals. The need for such wide bandwidth recorders of 4 GSPS with bandwidths of 1GHz are crucial to electronic signal analysis.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE - GDAS HEMT A/D	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1983-1984	DARPA work
2. First Experimental Device Application (or first experimental process demonstration)	1985	Rockwell Int.
3. When available for inclusion in product or process?	1988	Rockwell Int. TRW Honeywell

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Recording on magnetic tape of wide bandwidth Rf signals for analysis--i.e., spread spectrum signals.

B. To what products or processes might it be applied?

Radar receivers, electronic signal processors

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

EW and electronic signals intelligence capabilities would be greatly improved.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

EW and signals intelligence signal processing will be greatly enhanced by the ability to record 4GSPS at 1 GHz bandwidth signals. Real time signal processing of radar and other high speed signals can be interpreted for further analysis.

REPORTER: P.J. Boudreaux

AIDED BY:

TECHNOLOGY: Distributed, Automatic Communications Network & Link Control for Hostile Environments (D-8)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

1. Distributed control for survivable communications
2. Self-organizing networks
3. Adaptive reconfiguration under stressed scenarios
4. Layered protocols
5. Internetting architecture design (unified network technologies for mixed & multi media communications
6. Robust waveform & coding design for operation under hostile conditions
7. Distributed expert systems

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Distributed software development tools
2. VHSIC technology
3. VLSI technology
4. Microprocessor/computer technology
5. Local area networks

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

- Items 1-6 will be demonstrated by the end of FY87 under a S&NWSC 6.2 project entitled Unified Network Technology Demonstration (UNTD)

- Item 7 will be demonstrated by FY87 under UNTD and/or SDI

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military need! Important need for reliable and survivable communications under stressed environments.

Cost! Automation & computer technology should lower costs & reduce manpower needs.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration — #'s 1-6	1985	Many
#7	new	?
2. First Experimental Device Application (or first experimental process demonstration) — #'s 1-6	1970's apparent for some	DARPA
	1987 UNTD for others	S&NWSC
3. When available for inclusion in product or process? — #'s 1-6	SURAN 86	DARPA
	UNTD '90	S&NWSC

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Improved in Naval communication systems
   - Tactical sensor & weapons management
   - Reduce manpower
   - Improved throughput/efficiency
2. Internetting several distinct networks
   - Joint service interoperability
3. Application to SDI program - C^3 functions

B. To what products or processes might it be applied?

1. Emerging DoD C^3 programs

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. More reliable & survivable & responsive
2. Anti-jam design improvements
3. Cost savings due to internetting & tri-service interoperability (equipment reduction)

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

1. Improved C^3 in a hostile environment

2. Improved tri-service interoperability

3. Internetting provides backup services & improved throughput/efficiency of operating nets.

REPORTER: J.B. Hughes (S&NWSC)

AIDED BY: D.McGregor (NRL)

W.D. Long (NRL)

C³

TECHNOLOGY: Distributed Automatic Control of Communications Network(s) and Link Parameters in a Hostile Environment (D-8)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Development of protocols, algorithms, and architectures that allow various and multiple nodes to maintain communication in a hostile environment or in the event of node losses. The technology must address problems associated with information transfer over different media (e.g. voice, text, graphs, etc.) and frequencies with different waveforms, coding, etc. Furthermore, the technology must provide for automating the network reconfiguration in response to network degradation.

Technology(s) provides capability to achieve data transfer via dissimilar networks and communication bands.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Not applicable because primarily software related.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Parts already demonstrated:
a) packet radio for multi-network transfer (1983)
b) net control handoff for FLTSATCOM nets (1984)
c) robust HF algorithm (NRL 1984)
d) Adaptive data rate simulation (HF, NOSC 1979)
d) multi-media allocation for tactical data (command control processor) 1989

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Unknown by panel

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military
a) increasing threat
b) introduction of links that can survive threat environment (AJ) and processors to handle algorithms (e.g. C^2P)
c) need to use large inventory of existing comm equipment

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration (Many "pieces" separately demonstrated) -see 2A		
2. First Experimental Device Application (or first experimental process demonstration) Fully adaptive multi-media networks		
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Any heavily used comm network or set of networks. (Not needed for fully connected, lightly-loaded voice nets. Also not needed for unstressed networks--such as commercial--where centralized control is sufficient.)

B. To what products or processes might it be applied?

Military communication systems and networks in development and in operation today.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Provides communications survivability even when "net control node" is disabled. Also provides survivability of the network under a partial destruction of nodes.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Complements AJ techniques by protecting against the physical destruction threat and by allowing automatic adaptation of degree of AJ protection provided (e.g. by varying data rate).

REPORTER: ____________________

AIDED BY: Dale Long/Clancy Fuzak

Sherman Gee

Rabinder N. Madan

TECHNOLOGY: Distributed Automatic Control of Communications Network & Link Parameters in a Hostile Environment (D-8)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The access technology of future bandwidth limited communications systems requires the design of networking theories which apply to three dimensional (time, frequency, phase) access concepts. These developments should build upon ARPA & MILNET concepts to include "simultaneous" access to greater than 300 KB/S systems.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The effort requires extensive analysis of TDMA and DTDMA technologies and applications to distributed users throughout a hostile environment. Protocols of access must be modeless and adaptive to various user needs.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Need is now. Extensive effort is required for 1988 application to architectures.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US holds a lead in this area due to design in multifunction "radio" concepts.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military communications on a large scale in a hostile environment.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1987	Navy Lab
2. First Experimental Device Application (or first experimental process demonstration)	1988	Lab/Industry demo
3. When available for inclusion in product or process?	1989	Hughes

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Battle Field (Theater Warfare) Communication
Satellite Access
Any "constricted" communications problem

B. To what products or processes might it be appl'ed?

Telecommunications Systems

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Integrated communications systems by services (Interoperability)
- Communication in electromagnetic disturbance
- Greater use of satellite throughput capacity

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Provides alternate path communicators for tactical implementors. Allows for cooperative tactics in hostile environment (coordination of assets).

REPORTER: L. Morris

AIDED BY:

C³

TECHNOLOGY: Automatic Generation of Software from "Natural Language" (E-1)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Recent advances in Natural Language (NL) are based on interactive processes in which word meanings compete with one another to form coalitions within the discourse context arriving at the most appropriate meaning. This replaces strict dictionary look-up. Performance metrics need to be studied:

1) Level of allowable misinterpretation
2) Level of training required by users
3) Level of interactive verification of understanding required
4) Size of the domain involved

Coupled with the natural language technology is reusable software technology. Software "parts" or modules must be available which are machine independent. Metrics to determine degree of coupling to an instruction set architecture of a particular operating system must be developed.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Large Ada libraries must be maintained. Software metrics and measurement technology are crucial.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Reusable S/W libraries of parts will begin to be available by 1987. Software metrics and measurement techniques will be in place about 1987, but will continue to evolve. A realizable automated program generator should not be expected until the 1995 time frame.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Don't know.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Affordability of developing and sustaining SW is the driver. Billions of dollars can be saved by having standard, reusable software generated in fully documented, software engineered fashion. 85% of system life-cycle cost will be in software by 1990.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	Ada	Now	Navy, CECOM, Industry
	Reusable Parts	1986	STARS, CECOM
	Automated Program	1988	STARS, CECOM
2. First Experimental Device Application (or first experimental process demonstration)		1990-1993	STARS CECOM
3. When available for inclusion in product or process?		1995	SEI

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. *How might it be used?*

Development of SM for all military systems requiring real-time functionality. Used by developers and sustainers (Post Deployment Software Support Centers)

B. To what products or processes might it be applied?

Artificial Intelligence tools which "listen" to natural language and choose software parts that will link together to form a program are required. The efforts of the DoD software technology for adaptable reliable systems (STARS) and the Software Engineering Institute (SEI) as well as efforts at the US Army Communications Electronics Command (CECOM) and academia will advance the various technologies required. AI will probably be the driver. Use of Ada as the standard DoD HOL with its separately compilable modules will allow this technology to proceed.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Large cost savings will allow fielding of more military systems than otherwise possible. Acquisition cycle would be shortened to a few years.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Allow more systems to be fielded.

REPORTER: Joseph Pucilowski

AIDED BY:

Dep. Dir. Center for Tactical Computer Systems
CECOM, Ft. Monmouth

C-3

TECHNOLOGY: Automatic Generation of Software from Natural Language (E-1)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Research growing out of "automatic programming" efforts is leading to increasingly capable expert systems which capture the expertise of software developers. These systems allow programming at a more "natural" specification level (the "what") with automatic generation of executable code (e.g., LISP, Ada) (the "how").

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The development of this technology requires further advances in the expert system realms of knowledge acquisition and knowledge representation. Increased power in theorem proving techniques would also be extremely relevant.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

For large, practical, military embedded systems this technology (in same sense beyond Ada) will probably not be available before the year 2000. Smaller, practical applications should be ready earlier as a "successor" to Ada.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

The main work in this area has been U.S. (e.g., Green, Balzer, Cheatham, Rich), but realization of 5th generation goals will drive the Japanese in this direction.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The continued improvements in costs, speed, storage, compactness of the hardware technology means increased pressure to bring computer capabilities to non-professional, "naive" software developers.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Now	Green Balzer
2. First Experimental Device Application (or first experimental process demonstration)	1984	Green Acm Conf
3. When available for inclusion in product or process?	1995	STARS

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Virtually any military entity with a need for a new computer application could use a successful result from this technology. "End-user programming" with no reliance on professional programmers would be possible for modestly-sized applications. Professional programmers would find that the short-circuiting of the software life cycle would improve software maintenance activities and make "program verification" simpler.

B. To what products or processes might it be applied?

Satellites, air dropped and sub launched buoys, unmanned and remote electronics of any type both military and commercial.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Since this technology promises to lower software costs, its economic impact on the military would be significant. It would also permit much faster deployment of software-intensive military systems.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Increasingly "other" military capabilities are requiring a significant software component. Thus success in developing this emerging technology will enhance the development of these "others."

REPORTER: Norman Glick, NSA

AIDED BY:

C³

TECHNOLOGY: Parallel Processing (E-2/E-3/E-6)

(Related items: E-7 - Computer Language for Parallel Processing
D-3 - Mapping of Signal Processing Algorithms to VLSI Architecture)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Parallel processing implies the use of multiple processing units operating simultaneously on common input and stored data. The attraction is increased speed over single processors using the same technology. Efficient processor interconnection and memory access are the primary hardware problems. Propagation delay and bandwidth are potential interconnect problems (in addition to geometry). Historically, only highest speed applications make sense, since a larger, more costly machine can be built more cheaply than an array of smaller, less expensive ones. [DEC builds VAXs, not arrays of LSI-11s.]

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Key unknowns

a) Architecture. (Efficiency for various classes of problems. How to translate algorithms to architecture.)

b) High level, efficient language for such a machine.

c) Choice of interconnection technology (e.g. silicon-multiprocessor water, wire, fiber optics)

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Universities and labs have demonstrated various multiprocessor arrays--early 80's. Conventional technology, wire interconnection, (small machine interconnection) DARPA built in the 70's - super machine.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Unknown by panel

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Speed of processing. Users most likely are developers of extreme high-end computers, possibly military for signal processing.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	197X	DARPA
2. First Experimental Device Application (or first experimental process demonstration)	? ~ 1983	University X? NOSC (systolic array)
3. When available for inclusion in product or process?	1995	US

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Highly redundant architectures plus "self adaptive" software for fault tolerance (and possibly lower manufacturing cost)--small size; modest capability machines.

2. Applications requiring super computing power (SDI, weather prediction, war gaming, etc)--super array-type machine.

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. Both supercomputing and fault tolerant applications important aspects of SDI.

2. Supercomputing in general seems to have low impact--underused.

3. Fault tolerance has other, more direct redundancy approaches.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: C. Fuzak

AIDED BY:

TECHNOLOGY: Computer Language for Parallel Processing (E-7)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Design and development of hardware for parallel processing have far outstripped the associated software base. Software concepts have been dominated by classical "Von Neuman" sequential architectures. A fresh way of thinking about parallel software is needed. While individual processors present little or no problems, a global methodology for both control and data flow is required to begin to understand the problem.

B. List and describe related technology know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Ultimately, compilers must be developed to handle parallel software generation. Since there is already a myriad of hardware types, many compilers will be required. Two related technologies could offer insight for problem resolution. At the "grass roots" level horizontal microcode has a similar problem profile as many gate-level logic functions must be considered simultaneously. At the macro level distributed processing techniques, particularly those seen in networks should be applicable. Esoterically, one might model the "symphony orchestra". Each musician has a part to play throughout a score, but it is the conductor who pulls it all together and keeps the real-time output balanced.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Parallel software techniques are emerging now for specific applications. Critical mass for a cohesive compiler is less than 5 years away.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Major efforts in US and UK (Manchester Data Flow Machine). Japanese also pursuing. Latest proceedings of Parallel Processing Conference will contain latest available info. DARPA has something brewing but unannounced.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Problem set encompasses all sectors. Excellent opportunities for cooperative effort among academia, industry and military. Most efforts now specific application driven, i.e., systolic, weather forecasting, fluid flow, nuclear effects, etc.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Late 1980's	Academia Industry
2. First Experimental Device Application (or first experimental process demonstration)	Early 1990's	Academia Industry
3. When available for inclusion in product or process?	Mid 1990's	Academia Industry

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Total ICBM force management, sensor fusion, threat assessment, tactical and battlefield situations, improved surveillance and signals analysis, strategic computing initiative, "Star Wars", super computing labs, weather forecasting.

B. To what products or processes might it be applied?

- Database management systems
- Parallel processes with and without data/control dependencies
- Decision making and forecasting
- Reduce manpower intensive activities
- Make speech input/output to/from computers a reality

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Significantly improve capabilities mentioned in 3A if a cohesive compiler is developed. Military needs to look hard at Ada initiative and determine if a similar approach will work here or is even appropriate for this problem.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Parallel processing one important ingredient for developing more and better "system" capabilities as described above. A few more years to let the better ideas fully mature would help the military make smart decisions among which emerging parallel software generation techniques to choose.

REPORTER: Ted Yablouski DoD/CSC

AIDED BY: Norman Glick NSA

TECHNOLOGY: Computer Language for Parallel Processing (E-7)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The necessity for supercomputers of the future to have highly parallel, multi processor architectures results in a concomitant need either 1) to detect implicit parallelism in traditional languages (e.g., Fortran, Ada) or 2) to develop new languages which encourage "parallel" thinking. There are emerging technologies based on both approaches. There is a need, at least through the year 2000, for advances in both areas. Development on both control structures and data organization and flow are required.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1) For the implicit parallelism detection approach, compiler optimization "expert systems" will be needed to allow mapping from high level language statements to efficiently realized code on exotically configured multiprocessor architectures.

2) Human factors developments will be needed for wide acceptance of new languages and to determine the balance between human explicit awareness of parallel execution and language constructs that allow a compiler freedom to order operations and manage data as flexibly as possible.

Research on compilers for production of horizontal microcode and on distributed processing techniques should be relevant.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1) Efficient compiler for Ada for some multiprocessor architectures by 1995. Fortran is less than 5 years away.

2) A usable, high level language oriented toward efficient execution and highly parallel computers should be designed within the next 5 years.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

There is primarily a US effort, but substantial activity in Europe (especially UK) and Japan.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The speed of light limitation is forcing super computers to exploit parallelism. The full advantage of highly parallel computers cannot be realized without developments in this area. History shows that supercomputer needs eventually impact "ordinary" computers; thus, by the end of the century, everyone using a computer may be affected.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1) now 2) now	Kucle, Illinois APL, SASL,...
2. First Experimental Device Application (or first experimental process demonstration)	1) 1988 2) 1995	U.S. U.S.
3. When available for inclusion in product or process?	1) 1990 2) 1998	U.S. U.S.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Anywhere that supercomputers are needed in the near-term-strategic computing initiative, strategic defense initiative, weather forecasting, "large" knowledge-based system, nuclear event simulations. In the long-term, effective use of "ordinary" multi-processor computers (which ought to become widespread) may depend on development of this technology.

B. To what products or processes might it be applied?

- Software for supercomputers in the near term
- General software in the near distant future
- Widespread use of speech input and output depends on supercomputer developments

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Effective use of supercomputers has been a significant reason for the U.S. military lead. Developments in this technology will have a strong impact on the continuance of this lead.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Any place that embedded supercomputers are needed in the future will benefit by development of this technology.

REPORTER: Normal Glick, NSA

AIDED BY: Ted Tablenski, DoD/CSC

TECHNOLOGY: Ability to Deal with Large Masses of Data From Many (10^4) Sensor Locations in a Highly Cluttered Non-Stationary Environment, as in a Distributed System (E-8)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The problem of integrating from N distributed similar arrays with assumptions of independence of noise processes to improve direction of arrival estimates has been researched in a Navy program. Problem of integrated data for groups of similar/dissimilar sensors is being addressed at the conceptual stage. Developments in integrated estimation, detection, filtering and communication theories for distributed sensors are under way. Faster communications will be handled through laser technology providing high data rates for "local" networks of a subset of sensors. Security in communication can be handled by spread spectrum and data encryption, well advanced techniques.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- VLSI and VHSIC technologies.
- Developments in software for parallel processors would aid in speadier development.
- Need to be able to coordinate many high data rate comm channels with a robust networking concept.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1986-90 time frame.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Work at Fermi Lab and Cern (in Europe) in making high energy (GeV range) particle event decisions are made through a distributed system of computing processors (real and non-real time) attached to detectors. The systems have some similarity in concept with battle management systems. The link in concept with defense systems needs to be developed.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- Military and cost
- SDI

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1989	U.S.
2. First Experimental Device Application (or first experimental process demonstration)	1991	U.S.
3. When available for inclusion in product or process?	1993	U.S.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- SDI battlemanagement concept implementation
- Target acquisition, tracking and weapon control
- Multi-target imaging and discrimination
- Integration of weapon, sensor platforms

B. To what products or processes might it be applied?

- Manufacturing
- Banking distributed systems
- Communication networks

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

It will reduce information overload for principal operators in a battle-management situation by automating a subclass of decision making to local control centers. Improve efficiency by an order of magnitude.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   It will increase the sophistication of present distributed communication and data management systems, of protocol designs in the management of links and combined with means of reconfiguration of nodes improve survivability of capabilities in battlemanagement.

REPORTER: R.D. Madan, ONR

AIDED BY:

TECHNOLOGY: Design Principles for Substantially Improved Reliability of Electronics Systems (G-17)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- Artificial intelligence/knowledge based expert system research applied to aid in status monitoring, fault assessment and correction.
- Solid state devices for higher reliability for microwave radio, millimeter radio, and for satellite communication.
- Fault-tolerant processors especially for onboard satellite processors.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Full system reliability modeling (not just component or chip reliability) serially computed into the system value is needed to allow the system designer to make trade offs based on system driving parameters such as cost, MTBF, maintainability, security, etc. Reliability modeling can thus become an active part of system design instead of the often "after the fact" reliability assessment needed to satisfy procurement specifications.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

DARPA is applying AI to system management and control of packet radio networks. Air Force Space Division (Sunnyvale) is developing solid state devices and fault tolerant computers.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Japan is beginning strong in AI and fifth-generation computer. Japan is also strong in microwaves including solid state devices.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- AI is driven by the need to fuse together information from multiple-sources, process and recommend a course of action
- The need to reduce O&M for communication systems is a driver for use of solid-state devices on line-of-sight and tropo comms system

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

Extended life for satellites is a driver for fault tolerant on-board processors and also for solid state electronic devices.

MILESTONE	YEAR	BY WHOM
AI/KBEs for PRNET	1985	DARPA
1. Proof of scientific principle demonstration		
Solid State Device	1985	Multiple
Fault Tolerant	1979	AF Spectra
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- AI can be used in many applications to fuse together info from multiple sources, and recommend courses of action.
- Solid state devices microwave and millimeter LOS, tropo and satellite communication.
- Fault tolerant processors
- On board satellite processing
- More efficient network management and control of the Defense Communications System

B. To what products or processes might it be applied?

Communication networks like the Defense Communication System (DSN, DDN, DSCS, etc).

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Reduced O&M cost and fewer people
- Longer electronic system lifetime
- Higher system availability

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Reduced cost of system procurement based upon active reliability modeling weighted by system parameters.

REPORTER: Reilly

AIDED BY: P. Boudreaux

TECHNOLOGY: Design Principles for Substantially Improved Reliability of Electronics Systems (G-17)

I - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- The lead items in improving the reliability of electronics is through the careful application of CAD/CAM to LSI (configurable gate arrays--87) VHSIC, (sub micron --89). RF devices are improved through power FET developments--86, gallium arsenide devices--87 and monolithic design--87.

- An integrated CNI system design which will support the introduction of new technology has completed the exploratory development phase in 1985.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- CAD/CAM

- Thick/thin film manufacturing

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

• Configurable gate arrays	1987
• VHSIC Sub micron	1989
• Power FET	1986
• Gallium Arsenide	1987
• Monolithic Receiver	1987
• Architecture of systems for CNI allowing inclusion	1986

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

UK and others are also expending efforts in the r-f arena. Plessey is up with our level of advancement.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The life cycle costs of military equipments are now becoming the driving considerations as early as advance development design.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

None specified.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985-1988	Industry, NADC, TRW
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?	see above	Hughes, ITT, TRW, Rockwell, Singer

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Integrated systems as a vehicle to accept the advances in VHSIC, etc. (Interface definition, multiple bus architecture, etc.)
- By LSI greater reliability and less power in SRA designs

B. To what products or processes might it be applied?

Communications systems.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Platform reliability
- Affordable equipments

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

N/A

REPORTER: L. Morris

AIDED BY:

TECHNOLOGY: Ultra Low-Loss Fiber Optics (J-1)

1 - DESCRIPTION

A. **Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.**

Ultra pure fibers could allow communications over great distances without repeaters. Field splice/repair kits are a necessary related requirement. Commercial equipment has been demonstrated over 160 km ranges, but tactical applications have not yet reached this performance level. Major developments of new technology are needed to make fiber optics suitable to military applications, especially tactical, battlefield use.

B. **List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.**

Ultra pure "blanks" of glass. Film coatings to reduce moisture absorption. MODEMS, high quality optical converters.

Ultra low loss optical connectors for single mode fibers need to be developed for field splicing conditions. Alignment and coupling techniques outside "laboratory" conditions need further development. Methods for handling "taps" are necessary.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

U.S. Army, CECOM, Ft Monmouth, PMMSCJ/CENCOMS and ITT Corp. are developing fibers for communication and for fiber optic guided missiles for MICOM.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Japanese are producing commercial products at lower cost than U.S., defense applications of their R&D are not known.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military "down-the-hill" communication/covert, dispersed command posts/EMP protection/ECCM.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1983	ITT, CECOM
2. First Experimental Device Application (or first experimental process demonstration)	1986	ITT, CECOM
3. When available for inclusion in product or process?	1990	CECOM

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Covert, EMP proof communications for distributed command post and "down-the-hill" communications.

Defense Communications System.

B. To what products or processes might it be appl'ed?

Military radios.
Military communications

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Allow low-signature, ECCM command post operation to enhance survivability. Protection against nuclear effects. Allow dispersed operation.

Provide high bandwidth transmission capability.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Will allow distributed processing and data bases maintained at remote locations without providing RF signatures for enemy exploitation.

REPORTER: Joseph J. Pucilowski, Jr.

AIDED BY: A. Lubarsky

P.J. Boudreaux

J. Reilly

C^3

TECHNOLOGY: Automated Image Recognition and Classification through use of AI Techniques (L-1)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Involves converting 2-dimensional imagery (visible, infrared IR) into a symbolic representation which can be operated on by appropriate algorithms and expert systems to detect, classify, and/or identify objects or targets of military interest. Research to date has centered on determining:

a) Optimum internal machine representations for image data

b) Optimum mix of image processing and symbolic processing to detect/classify/identify given classes of targets as a function of imagery type.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

To equal the productivity of a human Imagery Analyst (IA), a two order of magnitude (at least) improvement in speed will be required. This can be achieved through a combination of more efficient software and higher speed computing machinery. To equal the accuracy of a human IA a factor of 2-3 improvements in algorithm/expert system reliability will be required.

The key to making this technology militarily useful will be the ability to create rapidly (days to weeks) expert systems for specific analysis tasks and the availability of symbolic processors which can run 3-4 orders of magnitude faster than those available today. Research currently underway in DARPA's strategic computing program may provide the requisite software and hardware technology in 3-6 years.

Implementation of a limited capability into an autonomous weapon (e.g. cruise missile) will require about a 2 order of magnitude decrease in size and power of computer hardware.

Optical signal processing technology likely to be important.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

- Limited capability should be available in the next 5 years.
- More robust IA system in 7-10 years.
- Missile applications in 10-15 years.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

U.S. work is probably the only real research in this area for military applications.

Some work in Japan on robotic vision systems.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Critical need to rapidly exploit large amounts of imagery for intelligence, targeting, and battle management. Needs in European theater war exceed productivity of available IA's by > 2 orders of magnitude.

Availability of fast symbolic processors will speed up availability of this technology.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1984	US DARPA
2. First Experimental Device Application (or first experimental process demonstration) — Laboratory scale hardware	1989	US-DARPA
Miniaturized hardware (missile)	1990-1995	US
3. When available for inclusion in product or process? — Large hardware	1992-1995	?
Miniaturized hardware (missile)	1995-2000	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Exploitation of reconnaissance imagery for tactical intelligence, targeting and battle management.

2. Automatic target detection and classification for autonomous weapons such as harassment drones, long range artillery, cruise missiles, and SDI.

3. Vision/navigation systems for autonomous land and air vehicles.

4. Machine assists to targeteers in aim point selection and weapon and fuzing selection.

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Current U.S. military doctrine requires that we rely upon deep interdiction (deep strike, follow-on-force attack etc.) in the prosecution of a tactical war in order to compensate for numerical deficiencies in the U.S. force structure. In order to accomplish the surveillance and targeting task in Europe for example, about 1/2 to 1 1/2 million sq. nmi of ~ 1 ft resolution imagery would need to be analyzed per day. Labor intensive methods fall short by about 2-3 orders of magnitude. The availability of this technology would make it possible to function within the context of existing doctrine and successfully prosecute a tactical conflict in Europe, the Middle East or Southeast Asia. Same comments in the Naval Theater where identifying major targets, isolated in the ocean, but surrounded by minor combatants and decoys, is the problem.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Rapid exploitation of imagery, coupled with effective second echelon and deep interdiction delivery systems could allow our planning and execution cycle to become significantly shorter than that of an enemy. While the effects have not been analyzed quantitatively, it is clear that the effect on an enemy is highly disruptive and can further enhance the usefulness of deep interdiction.

As robotics technology advances, the ability to process "visual" information will be highly desired.

REPORTER: John W. Hansen

AIDED BY: A. Brandenstein

J.S. Murday

TECHNOLOGY: Development of Automated Function Allocation Between Man and Machines in Complex C³ Systems (L-4)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Existing paper-and-pencil analysis used by human factors personnel in assigning functions between men and machines is tedious and error prone. An automated approach to this procedure is particularly desirable in complex C³ systems and would require:

- Computer-based data base involving compilation of a wide variety of human performance and reliability data
- *Development of AI algorithms modeling* human performance in complex man-machine systems
- Establishing optimizing algorithms (again, probably AI-expert system based) for assignment of functions between men and machines

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

No hardware developments required.

The following would be required:

- Establishment of software algorithms for human reliability and AI expert system optimized function allocation.
- Establishment of human performance reliability data bank, which would require expansion of efforts in the following areas:
  - embedded data-capture routines for operators in C³ systems
  - development of a good set of measures of effectiveness for C³ operators

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Expect that within next 10 years, automated human reliability data base and required AI algorithms will emerge.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US ahead--other countries with related efforts include Canada, UK, West Germany and Sweden

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Human error on the part of a C^3 operator often has disasterous consequences for overall mission success. Since the C^3 operator is often the bottle-neck in the system, the monitoring, control and decision-making functions assigned to him must be very carefully analyzed and appropriate trade-offs made. This is now beyond the paper and pencil phase and requires computer assistance in making the determination.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985 (Limited Data Base)	USAF Labs
		Navy Labs
		Nuclear Power Irdustry
2. First Experimental Device Application (or first experimental process demonstration)	1992	"
3. When available for inclusion in product or process?	1995	"

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Determination of manning requirements for complex C^3 systems
  - Type of personnel
  - Number of personnel
- Greater predictability regarding system reliability
- Greater predictability of overall mission success
- Computer simulation of proposed C^3 systems

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Increased probability of mission success by reducing probability of human error/misjudgement through optimized function allocation
- Reduced manning within C^3 systems
- Lowering of training requirements for C^3 personnel

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

If used in conjunction with decision-support AI programs, this would insure that the C^3 operator is:

- doing what is best left to the human
- receiving the best information required to successfully perform his task

Dr. Robert Fleming NPRDC
REPORTER: NPRDC (202) 692-4860

AIDED BY:

TECHNOLOGY: Speech Recognition (L6,7)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Speech systems with a limited vocabulary, requiring clear pauses between words and operating in a speaker-dependent mode are available today. A technique of template matching with dynamic programming has been utilized for such systems. However when vocabularies become large, the need to train the system and the need to acquire the necessary templates become time consuming; also the pattern matching algorithms become too slow. Feature base recognition technology which attempts to identify the acoustic features that are needed to define speaker independent patterns are finding limited success mainly due to our lack of knowledge of the invariant relations among linguistic features. Continuous speech is considered more complex because the acoustic signal is often altered at word boundaries. Using template matching twice, once for single word matches and once for group of connected words with relaxation of the matching criteria at word boundaries have met with limited success. Continuous speech systems are still speaker dependent and possess limited vocabulary.

B. List and describe related manufacturing know-now, keystone equipment or

The following advances are required:

1) Increase in knowledge of invariant relations among linguistic features

2) Custom VLSI chips to obtain the computational speeds required

3) Utilization of preceding words to determine current word

4) Faster search algorithms

5) Codification and utilization of constraints imposed on the sound patterns of a language

6) Utilization of the context or knowledge of the subject discourse to interpret the sounds

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

See D below.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

There are several companies in the U.S. (IBM, ITT, Bell Labs, GTE) as well as several universities (CMU, MIT) and DoD agencies (DARPA, USA CECOM, RADC) that are performing research or have demonstrated speech recognition systems. Japan (Nippon Electric Co.) has also demonstrated a speech recognition system and is actively pursuing research in this area. The continuous speech systems are usually speaker independent (several speakers only) vocabularies of less than 5,000 words with unlimited syntax with speaker independence.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The recognition of the importance of this technology and the infusion of dollars with a concentrated concerted effort.

"Consumer" applications--automatic transcription ("typing"), automatic language translation.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	CAPABILITY UNLIMITED SYNTAX 20,000 WORD SPEAKER INDEPENDENT	YEAR	BY WHOM
1. Proof of scientific principle demonstration*	discrete	1987	Japan, US DARPA, CECOM
	continuous	1992	
2. First Experimental Device Application Application (or first experimental process demonstration	discrete	1989	"
	continuous	1995	
3. When available for inclusion in product or process?	discrete	1990	"
	continuous	2000	

*Proof of principle has already been demonstrated using some of the techniques described above. Also NL systems have also demonstrated other techniques that could be adapted.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Speech systems would serve as front ends to natural language understanding systems in order to acquire data that is transmitted by voice to a command and control systems. The signals may be requests by the user to the C^2 system or it may be information provided to the C^2 system for inclusion in its data or knowledge base.

B. To what products or processes might it be applied?

The five functional segments of command and control (fire support, maneuver control, air support, combat support and IEW). It can also be utilized by operators in tanks, aircraft, etc., to control and operate these vehicles.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Could improve efficiency of information processing and could allow operators to simultaneously perform other tasks. Efficiency improvement in problem solving is roughly 2:1 over keyboarding--but, as in keyboarding, visual feedback is important in critical applications.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Improve the effectiveness of command and control.

REPORTER: Dr. Martin Wolfe, U.S. Army/CECOM

AIDED BY: C. Fuzak

TECHNOLOGY: Threshold Logic for Decision Making in Situation of Incomplete Information (L-17)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The world is not entirely binary. Higher level algebras (multiple-value) have been studied and debated for at least 15 years. These algebras form the basis which allows more than "yes-no" thinking. One form of this methodology, "fuzzy logic", addresses the problem at hand. Also, there appears to be a "connection" between multiple value logic and multilevel security. It has been difficult to map theory into practice.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Two notable events in 1984 have rekindled interest. A small firm on the West Coast announced an "influence" type chip. (Actually the chip allows one to choose the six 32-bit vectors closest* to a prescribed one.) A professor at Queens College in Canada built a prototype ternary computer (based upon classic von-Neuman architecture). The professor used off-the-shelf CMOS to achieve his machine. More importantly Bell Northern is mapping the professor's designs to VLSI. Both of these efforts are good evidence of reducing to practice at least the hardware. Both fall short in software support.

* in a Hamming sense

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technology is here. Biggest problem has been closure on viable components put together in real system applications. Will be early to mid 90's before see commercial products.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Appears to be more interest outside U.S. and among academic community. Growing industry awareness. Strong binary bias must be overcome.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Must show that multiple value systems can augment current binary systems. More gaps in technology should be given a look from this perspective.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1970	Many
2. First Experimental Device Application (or first experimental process demonstration)	1984	U.S., Canada
3. When available for inclusion in product or process?	1992-1995	U.S., Canada

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Decision making where more than two alternatives
Artificial Intelligence and Expert Systems
Tough problems like sanitization of data
New algorithms/new processes (architectures)
Light-based computers
Multilevel security

B. To what products or processes might it be app'ied?

New methods of analysis/synthesis
Parallelism in levels as opposed to machines
Extend binary (when limit reached) for storage, processing, transmission
Residue number systems
Cryptography

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Enhance AI and Expert Systems development
Provide a basis for holistic decision making
Solution for Database "Inference" problem
Solution for Data Sanitization

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Could create new industry of across-the-board development in computers and semiconductors. Influence logic design, architectures, operating systems, hardware/firmware/software verification. New way of thinking about old problems. Some optical phenomena which are ternary in nature could be basis of a light-only computer.

REPORTER: Ted Yablonski DoD/CSC

AIDED BY:

C^3

TECHNOLOGY: Decision Support for Military Decision Making (L-18)
Note: This write-up is more general than the AI-oriented write-up submitted by Al Brandenstein.

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Decision support involves many technologies:

1. Data correlation--algorithms to correlate/associate data from diverse sources
2. Data processing--hi volume, hi speed (>10^8 MIPs) filtering and manipulating into convenient formats
3. Distributed database management--distr. op systems, database access, queries, updates involving different DB's

(Items 2 and 3: Real Time)

4. Displays--large screen displays with resolutions 2000 × 2000 lines or better
5. Data transmission--local area networks (~10^8 Hz) transport and control protocols
6. Knowledge-based systems--AI techniques for higher levels of automation
7. Human factors--man-machine interface, measures of effectiveness

The major challenge is to integrate diverse technologies into command decision support systems that enables timely decision making for mission planning and situation assessment.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Above involves both hardware and software technologies, primarily in the latter. Hence, this question not entirely appropriate. In the hardware area, keystone technologies would be:

1. Displays--laser addressed liquid crystal light valve technology appears most promising today to achieve hi resolution large screen displays (2000 × 2000 lines or better)

2. Data transmission--fiber optic databases and interconnects for high speed data transmission (100 MHz and higher)

3. Knowldge-based systems--expert systems are currently highly problem specific. Difficult to project situations requiring hi volume production.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

High resolution large screen displays--1990
Knowledge-based systems--1987 - 2000 (some becoming available now)
Distributed DB Mgt--1995
Data processing (supercomputers for data and symbolic processing)--2000
Human factors--1989

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Not familiar with non U.S.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military threats--primarily multiple, high speed missiles
Decision analysis in industry.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	Hi resol lge screen dis Dist DB Mgt KB Systems Supercomputers	1983 1985 1975? 1990?	US/NOSC US/CCA Corp US/Stanford US/CRAY
2. First Experimental Device Application (or first experimental process demonstration)	See above		
3. When available for inclusion in product or process?	Hi resol lge screen dis Dist DB Mgt KB Systems Supercomputers (MVM+Symbol)	1990 1988 1985 1995	US/NOSC US/CCA US US/Japan

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Relieve information overload faced by military commander by increasing degree of automation for decision support.

B. To what products or processes might it be applied?

Command center operations
Tactical action officer operations

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Currently, operational personnel will not be able to handle and assimilate the volume of information form all sources and to make necessary decisions based on this information in the time required to respond to attacks from multiple, hi speed threats.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Synergism of component technologies as described herein is to provide more automated military decision making itself. Synergism of component technologies is the key to more effective decision making.

REPORTER: Sherman Gee

AIDED BY:

C^3

TECHNOLOGY: Decision Support System for Military Decision Making (e.g. for Efficient Task Assignment and Planning) (L-18)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The technologies which would allow military utilization of advance decision support system concepts for military decision making include artificial intelligence rule based systems, generic expert system building tools, natural language interfaces, large scale data bases. Successful accomplishment requires natural language interfaces to expert systems, robust natural language interfaces with breadth, knowledge acquisition tools, planning and reasoning tools.

The domains of today's expert systems are extremely limited. They deal basically with diagnostic or configuration type tasks. These systems possess several common characteristics. They all obtained their domain knowledge from a recognized expert in the field. Usually a single expert was utilized for this purpose. The knowledge or skill needed in performing these tasks required little or no common sense. The knowledge domain was static in that it did not change over time even though the expert's knowledge of the domain might have changed over time. During development, a knowledge engineer was utilized to extract the knowledge from the expert and develop a representation for the knowledge. In addition, because these systems were unable to "learn", they must be continuously maintained and updated by the knowledge engineer. Finally, today's expert systems do not possess general knowledge upon which they can fall back when encountering unexpected problems. They don't degrade gracefully.

Techniques for acquiring knowledge from multiple experts and the ability to recognize, evaluate and correct conflicting knowledge would be required for military systems. In addition since data on the battle field is constantly changing, the information on which commanders draw conclusions from is not static but dynamic. Therefore the need to maintain consistency in the knowledge base must be addressed as well as the ability to represent and reason with redundant as well as incomplete or erroneous data. Interfaces to expert systems would have to be natural and compatible for the user. Area of graphic displays, voice recognition and natural language understanding offers promise in this arena.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

EXPERT SYSTEM TECHNOLOGY: Generic expert system tools must be developed spanning the military domain of interest to the three services, knowledge acquisition tools, explanation, planning and reasoning.

NATURAL LANGUAGE INTERFACES: Breadth, robustness, large domains

NEW MACHINE ARCHITECTURES: Development of the Butterfly machine to allow distributed processing for war gaming models/analyses, development of the connection machine to assist in the dynamic assessment of battlefield, war game scenarios and contingency planning.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

EXPERT SYSTEM TECHNOLOGY: Commercially available today with limited reasoning, must be transferred to pertinent military domains. Within five years: planning and reasoning systems of a primitive state, knowledge acquisition tools, expert systems accessed by natural language interfaces, natural language interfaces with large military vocabularies and domain flexibility.

NATURAL LANGUAGE: Text generation within five years, text understanding within five years.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

The US has the lead in expert system tool technology; Japan and Europe are behind in basic research.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The military has specific needs; the military domain has many features distinct form the civil/commercial sector. The military has a need to develop decision support systems which draw upon the expertise of many individuals, i.e. the medical-diagnosis area used a doctor while an expert system developed in a command center must use officers/enlisted who are on 3 year tours, and who all have some part of the needed expertise. Expert systems tools must be developed which can handle these unique features of military planning centers.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
Natural language interfaces (NL menu)	1984	Commercial sources
Expert systems for VAX configuration/oil prospecting/medical diagnostics	1978 -83	DEC Corporation, universities
Natural language interface to expert system	1986	DARPA
Testbed established at CINCPACFLT	1985	DARPA
Cooperating expert systems to aid decisions	1987	DARPA, CECOM
Testbed to develop required decision support systems engineering principles for a large military enterprise	1987	DARPA
2. First experimental device application (or first experimental process demonstration)	1988	DECOM
3. When available for inclusion in product or process?		
Transfer to Navy C^3 system ashore	1988	DARPA
Transfer to navy C^3 system afloat	1988	DARPA
Transfer to JCS/Army	1988	DARPA
Transfer to PM OPTADS	1989	CECOM

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Management of the daily planning, contingency operation functions of a major military command center, preparation of war plans, war gaming support for a major military command center, battle group commander offensive and defensive planning support, BG defense, afloat management of battle group simultaneous with ashore CINC responsibilities.

B. To what products or processes might it be applied?

PROCESSES SUPPORTING ANY LARGE SCALE ENTERPRISE: Commercial or military, intelligence analysis, forecasting, corporate planning, corporate management, production scheduling, etc.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

A major command center could perform a contingency response task more completely in less time, i.e., a larger number of options could be examined and retained for longer time, less staff personnel should be needed. For the BG situation, an afloat commander could manage the BG mission and when directed, without augmentation of officer/enlisted staff manage part of the CINC area-wide task. Transfer of command ashore to command afloat is a major objective to ensure enduring command during war time. It can provide the commanders with the ability to make decisions within the enemies decision cycle.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The capability from AI must be coupled to the massive investments in data base systems. ADP support to achieve fundamentally more rapid, more sophisticated decision support. Option generation in the presence of uncertainty, done manually today, would be done with capability to retain more options for longer periods of time.

* The write-up provides an entirely AI perspective on the military decision support problem. For a broader (non AI) description of the technologies inherent in decision support, see separate write-up by S. Gee.

REPORTER: A. Brandenstein (DARPA)

AIDED BY: Martin Wolfe (CECOM)

REVIEWED BY: Sherman Gee

TECHNOLOGY: Synergistic Monitoring of Human/Machine Operational Readiness (A-20 + L-20)

I - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Very large amounts of money have been spent on monitoring the operational status of C^3 equipment. Very little money has been spent on monitoring the other major component of C^3 systems: the C^3 operator/watchstander. Recent developments in the related fields of microminaturization and biotechnology have shown great promise in developing the hardware and measuring techniques for determining the status of an individual's alertness/health. Of particular promise are those areas involving neural recording of cortical potentials.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Dramatic advances in hardware. Remaining development area is establishing correlational link between physiological recording and current alertness/vigilance state.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Small, portable, non-intrusive hardware should be ready in 5-10 years. Determination of physiological correlates will be an on-going process but should show enough gains within the next 10 years to develop some valid and measurable indices.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

All industrialized nations--US may not have lead.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The increasingly small pool of trained C^3 operators will require that determination be made, prior to the start of a watch, that the operator is sufficiently alert/healthy to begin the watch. Similarly, his condition must be monitored during the watch to ensure that he is not lapsing into an unacceptably low level of alertness. Particularly important during long duration "GQ" conditions.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985	US industry Govt DoD labs
2. First Experimental Device Application (or first experimental process demonstration)	1994	"
3. When available for inclusion in product or process?	1996	"

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Alertness of C^3 operators
- Alertness of guard force e.g. nuclear weapons security
- Determination of watchstanding schedules
- Pre-selection of promising personnel
- Drug/alcohol detection

B. To what products or processes might it be app' ed?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Better C^3 decisions
- More effective watchstanding
- Improved personnel screening
- Quicker/more accurate threat detection and assessment

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

It is viewed that this would be a mutual monitoring systems, i.e., the C^3 operator will monitor the status of his equipment on his primary display, while at the same time the C^3 operator's status is being monitored by minaturized electronics (e.g. brain wave recordings). If the operator's monitor system detects problems with the operator's state of alertness, warnings would appear on the operator's primary display (and, if appropriate, on the supervisor's display so that he could be alerted that one of his staff is having problems).

REPORTER: Dr. Robert Fleming, NPRDC (202) 692-4860

AIDED BY:

TECHNOLOGY: Chemical Microsensor (Reflects ET Suggested in A-20, L-8, G-2)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Advances in information processing beg for improvements in info acquisition. Miniaturization of electronics and optoelectronics has raised the surface/interface to volume ratio. Sensitivity to chemical moieties in the ambient is a problem manufacturers of electronic devices work hard to avoid. That sensitivity provides an opportunity to develop a new class of specific chemical specie sensors in a fluid phase with the following properties:

- dimensions less than 1 cm × 1 cm × 1 nm for each sensor
- signal output compatible with microelectronic technology
- low power requirements (milliwatts)
- sensitivity to 1 part per million or lower concentrations
- ability to correct for temperature and pressure fluctuations
- selectivity to a specific moiety, or the capability to use an array with pattern recognition techniques for selectivity
- response time of one second or less

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Examples of such devices include:

Electronic device	Property change detected
FET	Dielectric contact
SAW	Density, elastic modules
Microelectrode array	Conductivity
Microelectrode	Oxidation/reduction, conductivity, potential fluctuations
Optical waveguide	Index of refraction

1. Development of coatings to physically or chemically react with specific fluid phase species and undergo a change sensed by the electronic or optoelectronic device.

2. Develop techniques for applying the appropriate coating on a sensor.

3. Assessing reversibility and longevity of the coatings.

4. Develop multiple sensor arrays with different coatings and/or different devices to use with pattern recognition techniques to get selectivity.

5. Develop technology of manufacturing the sensor and data processing electronics on a single chip.

6. Develop fluid pumping, particulate filtering and general flow technology to circulate fluid about sensor array.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Specific sensor/coating pairs are under evaluation in several laboratories with 1 ppm sensitivity and 1 sec, reversible response times.

1990 for commercial sensor packages for benchtop or wallmount
1995 for commercial packages in cigarette pack sizes

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

U.S. ahead, with Europe and Japan close behind.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- Military has critical need in CBW, also hazardous gas and engine status monitor

- Industrial has hazardous gas monitor chemical reaction process control, possible use in automotive exhaust and engine carburation control

- Environmental has fluid monitor needs for noxious or hazardous chemicals in general environment and specifically at dumpsites.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980	NRL Univ Utah
2. First Experimental Device Application (or first experimental process demonstration)	1983	NRL
3. When available for inclusion in product or process?	1990 1995	"lg device pkg" "sm device pkg"

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. CBW - Alert to chemical/biological attack, either at fixed stations or individual level. DON/DOFF indicator. Assessment of decontamination success and possible recontamination following partial decontamination.
2. Fire - Detection of fire via chemical species emitted, possible identification of type of fire, include with CBW sensors in damage control system.
3. Fuel, lubricant, hydraulic fluid monitor for degradation leading to system failure or intrusion of deleterious species such as water.
4. Monitor physiological status of humans to detect fatigue or illness.
5. Hazardous gas monitor to detect presence of gases hazardous in a particular environment--CO, CO_2 in enclosed human spaces, silicones or hydrocarbons around high current electrical branches, etc.

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. Present inability to sense presence of CB agents poses major problem to DoD. Heat load in protective garb limits use to 1 hour; pilot vision and response time severely restricted.

2. Engine status monitor on ground vehicles, aircraft and helicopters will improve failure prevention, reduce time between overhaul.

3. Damage control information vastly improved with subsequent improvement in CO decisions.

4. Air traffic controllers, pilots and other operators who require a high state of alertness to perform their mission; benefit from a monitor of fatigue or malaise.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The continual evolution of microelectronics smaller size, lower power and faster processing will require improvements in information acquisition. The chemical microsensor, and its parallel in physical property microsensor, will enhance the power of robotics and process control.

REPORTER: Dr. James S. Murday, NRL Code 6170

AIDED BY: ____________________

TECHNOLOGY: Millimeter Wave Radio Including Low Noise Receivers and Solid State Power Amplifiers (D-5)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Millimeter wave radio provides wide bandwidths in an uncongested part of the electromagnetic spectrum. Solid state technologies need to be extended to operate at mm frequencies. Some technologies include: gallium arsenide field effect transistors, Gunn diodes and Impatt diodes.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Transferred electron devices (TED) along with Gunn effect devices need new materials to exploit. Structures in super lattice materials such as GaAs (and other Group III-V compounds) offer great promise. Materials fabricated to optimize band gaps and high mobility for exploiting negative differential mobility can be made with molecular beam epitaxy (MBE) and other related growth technologies.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Now to next five years.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Japan is a leader along with U.S. in mm satellite technology development.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Wide bandwidth for anti-jamming protection

Availability of frequency spectrum not already in use.

Improving survivability of Defense Communications System

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1960-1970s	Industry
2. First Experimental Device Application (or first experimental process demonstration)	Now to Near Future	Norden Hughes Hazeltine Motorola Sperry
3. When available for inclusion in product or process?	Near Future	ITT AIL

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

MILSTAR EHF

Future defense satellite communicant-system EHF upgrade (proposed)

Navy EHF program

Defense communications system line of sight microwave

US Army communications command base communications trunking and digital distribution

Complements fiber optic for wideband transmissions

B. To what products or processes might it be applied?

Communications systems

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

mm waves allow rapid extension and restoral of communications because frequency spectrum is relatively unused

wide bandwidths allow the use of spread spectrum techniques for protection against jamming

narrow antenna beamwidths provide for antenna discrimination against jammers

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Reilly

AIDED BY: P.J. Boudreaux

C³

TECHNOLOGY: Advanced Communications Switching Techniques (D-21)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Optical switching of video communications (analogues to present voice switching but for video)

Integrated switching of voice data, facsimile, etc.

Advanced switching concepts for wideband requirements such as video wideband services.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

ATT is developing fast packet switching, which can handle various types of service.

GTE is developing burst switches.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Internationally the world is evolving to an integrated services digital network which provides integrated services from the user to the end office. The next step is to integrate the backbone switching.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Economy and interceptability

An integrated network can replace separate packet switching network (like DDN) and circuit switching network (like DSN).

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
First Experimental Device	1980	GTE
Application (or first experimental process demonstration)	1984	ATT

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

As part of Defense Communications System (following DDN & DSN)

For future echelon above corp switching for tactical user

B. To what products or processes might it be applied?

Communications network

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Significant cost and manpower savings by eliminating the need for separate "data" networks and voice networks
- Enhanced interoperability by designed compatibility with international standards (ISDN)

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: J. Reilly

AIDED BY:

C³

TECHNOLOGY: Computational Methods Using Numerical and Symbolic Data (E-11)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The real world is represented in computers as data objects which can either be numeric, composite or enumeration types. The ability to type data objects is provided by several languages. In the field of artificial intelligence the language LISP is used by the US and PROLOGUE by the Japanese. In the area of abstract data types the US and European countries are using Ada. The difficulty with such a general subject as computational methods is discovering which particular problems require exploration and research.

In the numeric category, one example is the methods dealing with angular rotation. Research in algorithms which maintain othogonality during propagation of direction cosine matrices rapidly expanded into military systems until the rediscovery of quaternians. This method of using four part space to translate vectors is used more frequently in missile and space applications. However this numerical computational method is clouded with confusion and misinformation.

Research could identify and resolve the controversy in this area and other important computational schemes from either the AI arena or the numeric processing category.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The use of an appropriate language whether it be Ada, LISP or some other higher order language (HOL) in a Department of Defense (DoD) standard computer is the most productive environment for research in unique computational methods with military application. Computational methods are bounded by the speed and word size of the computer for which they are intended.

- The ability to create abstract data types and to define the applicable computational operations which could be performed on the data is provided by Ada. The evolution of the classical numerical analysis techniques into AI or abstract data types must occur before any practical application will be realized.

  Production of software computational methods is not so much of an issue as the ability to reuse algorithms once they are operational.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

   Depending upon whether one is considering AI computational methods or the more classical numerical analysis schemes, the time will vary between 4-8 years

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

   The Naval Weapons Center (NWC) is building an expert system for the Sparrow missile. Several Japanese and American companies have projects developing AI products. Military Ada applications are being implemented by the NWC on the SEA LANCE missile, Northrup on the F-20 and MacDonald Douglas on the F-15. The extent of research dealing specially with computational methods using either numerical or symbolic data is unknown to the reporter.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

   Funding is scarce to develop specific computational methods without an immediate application. The academia uses graduate projects to investigate selected subjects in the ET field; however, this work tends to solve theoretical issues vice the pragmatic issues of concern to the military.

   Clear managerial direction is not perceived as being given to the Software Engineering Institute at Carnegie Mellon University to explore this software issue.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1995	Military labs, Academia
2. First Experimental Device Application (or first experimental process demonstration)	1975-1985	"
3. When available for inclusion in product or process?	1986-1990	Contractors, Military labs

3 - APPLICATIONS

Describe the potential military applications of t·is ET:

A. How might it be used?

Missiles require high performance computational methods which can efficiently and accurately manipulate large volumes of numerical and symbolic data. The areas of robotics, unmanned aircraft and cruise missiles have particular requirements for computational methods. Space vehicles, aircraft, ship and command centers all use computers whose capabilities and throughput could be enhanced by improved computational methods.

B. To what products or processes might it be applied?

Radar signal processing, guidance laws, control theory, statistical sampling schemes, filtering, weapons delivery, and navigation are but a few of the many disciplines this technology could affect.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The present accuracy and capability of the various embedded tactical computer systems is directly proportional to the power and accuracy of the computational methods implemented in the computers. Therefore the US could improve many weapons by replacing or upgrading the antiquated algorithms used.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

New methods combined with more powerful HOLs and computers will produce a new generation of computer systems which have more capacity for complex operations, more accuracy and more sophisticated information processing.

REPORTER: Carl W. Hall

AIDED BY:

C3

TECHNOLOGY: Computational Methods Using Numerical and Symbolic Data (E-11)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Computational techniques that can accommodate scientific computation, data processing and symbolic processing associated with AI machines. Higher order languages commonly encountered are:

scientific--FORTRAN
data processing--COBOL, ADA
symbolic--LISP, PROLOG

Most research currently conducted on AI machine architectures. Software research in functional programming, object-oriented programming. R&D trend is toward AI machines with increasing levels of performance and human reasoning.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Not applicable because technology is primarily software. Availability of appropriate HOL compilers and their performance would affect widespread adapter of computation techniques of SW developed.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1995

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Non US unknown. Japan and US leaders, but progressing along different lines in symbolic programming (PROLOG vs. LISP).

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Higher degree of automation in military and industrial arenas.

Military: AI for decision support, natural language processing of message, automated software production.

Industry: Manufacturing processes and control
Production of SW
Electronics maintenance and design

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1970s	US/Stanford
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?	1995	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Applicable at all levels of military command structure for wide variety of mission areas:

Surveillance - target classification

C^3 - decision support
- SW production and testing
- network control

EW - ESM, signal sorting

Weapons - smart sensors

B. To what products or processes might it be applied?

Future products or processes requiring computations of multimedia data i.e. numbers, symbols, graphs, texts.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Relieve manpower intensive operations.

Broaden scope of processes amenable to high speed computation.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Development of numerical and symbolic computation methods should progress in tandem with development of AI machine architecture. Bottom line determined by synergistic combination of both SW and HW developments. When combined with other technologies (e.g. distributed DB management, large screen displays) would provide the military with ability to manage tactical or strategic information in the time frames required to meet anticipated threats.

REPORTER: Sherman Gee

AIDED BY:

C^3

TECHNOLOGY: Computer Security (E-19)

I - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Becoming a critical problem for entire Federal Government. Criteria exist for trusted computing system development. Multilevel security is root problem. Need to reduce and limit exposure of classified data to those authorized to view same. Touches all areas of automated information systems in academia, industry and government. Must address processing, storage, and transmission aspects of classified data by/through computers of all types.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Some vendors have produced products which support varying degrees of computer security. The technology is in-hand to produce more secure machines. Incentive has been lacking, but a growing customer demand is required to convince most vendors that machines with security are viable in the marketplace.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technology available to produce verified software design. Verified software implementation (including hardware) remains an elusive target Should see something in 90-95 timeframe.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Very little happening outside US. Closed societies enforce strict procedural controls for data dissemination. Handful of applications in defense system employ sanctioned products.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need to control classified information disposition. Cost an important factor--most systems can only tolerate a 10-15% delta for security. Also, inclusion of security <u>should not</u> significantly degrade system performance.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Mid 70's	NSA USAF
2. First Experimental Device Application (or first experimental process demonstration) Blacker Multics	Late 70's	NSA USAF
3. When available for inclusion in product or process?	Now to 1995	CCSP

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Reduces vulnerability of sensitive military systems. Will reduce security cost if can reduce number of clearances. Use in both strategic and tactical environments. Provides all echelons a value-added service, i.e., maintains confidentiality where required.

B. To what products or processes might it be applied?

Military Message Systems
Database Management Systems
Intelligence Information Systems
Logistics Systems (including Personnel Actions)
Surveillance and Early Warning Systems
Force Management Systems

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Significantly improve all aspects of military operations and preparedness. Better security places tremendous pressures on adversaries, particularly in times of stress. Provides an equalizer in our open society when compared to closed ones.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Currently a consolidated computer security R&D program (CCSP). Players are Services, DIA and DCA. DoD/CSC orchestrates initiative, currently in 3rd FY. While emphasis is on development of generic capabilities, there are a few application specific projects (of critical need). Overall program embraces computer architectures, database management systems, network security and the software verification environment. Equally important is the evaluation aspect of systems that are or will be certified secure according to DoD/CSC criteria. A major tool development effort is under way that will enable the services to eventually help in this area (similar to what has been done in TEMPEST).

REPORTER: Ted Yablonski, DoD/CSC

AIDED BY: Joe Pusilowski, Army

Ken Alange, NAVELEX/Navy

John Faust, RADC/USAF

TECHNOLOGY: Computer Security (Multi Level Secure OS) (E-19)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Multi-level secure operating systems proven to the A-1 level are emerging. An OS tailored for message traffic (SCOMP) has been developed. Tactical database management systems combined with a secure OS allows transfer of required data throughout a battlefield.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Verification tools for secure OS (multi-level) - Computer Security Center and CECOM, 1985

Multi-level secure OS - CECOM, 1988

Tactical database management system integration - CECOM, 1991

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need is purely military as data is passed in distributed fashion between echelons and battlefield is dispersed. Essential for "see deep" capabilities.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985	CSC CECOM
2. First Experimental Device Application (or first experimental process demonstration)	1988	CECOM
3. When available for inclusion in product or process?	1990	CECOM

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

As part of fully distributed battlefield or strategic system where information of various classifications must be processed.

B. To what products or processes might it be applied?

ASAS system.

WWMCCS

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Allow easier, more rapid distribution of data to allow plans to be revised within decision cycle of enemy.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Joseph J. Pucilowski

AIDED BY:

TECHNOLOGY: Electronic Materials and Devices: Synthetic Non-Linear Optical Materials Custom Designed for Specific Applications (G-1)

1 - DESCRIPTION

A. *Describe the emerging* technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The ability to make highly stoichiometric (<0.1%) and pure (<<1 ppm) optical crystals relatively defect free (strain not detectable to x-ray topography) is being demonstrated. When combined with in- and out-diffusion techniques and/or epitaxy, devices can be fabricated employing electro-optic as well as second and third order purely optical effects. In some materials reduction of losses by laser annealing has been demonstrated.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Processing technologies such as highly perfect crystal growth, surface diffusion, and heteroepitaxy are being applied. Characterization capability such as synchrotive x-ray topography, neutron activation analysis, neutron diffraction/crystallography, advanced electron microscopy, and advanced surface analysis techniques are required. Materials receiving primary initial attention are lithium niobate, potassium niobate, bismuth silicon oxide, a variety of organic materials, and in the longer run, modulated layered structures.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Lithium niobate is available commercially, but devices made from are so far unreliable. It should be available in a reliable form within five years if attention to crystal growth and device fabrication is given.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Emphasis has been given in Japan and the UK as well as the US. Since no devices are available commercially it is not obvious that any specific country is far in advance.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Needs include speed and capacity in image processing and analysis as well as in communications. In the process, costs are lowered. Devices are insensitive to severe EM pulses. Opportunities include the ability to determine and control critical structural features in order to make satisfactory material. Devices with a 1-2 cm^2 area are possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	~1970	Bell
2. First Experimental Device Application (or first experimental process demonstration)	~1975	Bell
3. When available for inclusion in product or process?	1990?	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Switching and modulation of signals for communications exceeding current bandwidth capability are feasible with integrated optic devices. Real time correlation of image information is possible with spatial light modulators. Similar processing of three dimensional information as well as storage are possible with volume holographic elements.

B. To what products or processes might it be applied?

Communications with a bandwidth in excess of 2G bit/s is now feasible with such materials. Optical signal processors either with high capacity in real time capability are also possible. These opportunities seem most promising for parallel processing

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Through high-speed communication real time and quasi-real time analysis by by large scale central computers can be made available to surveillance and response operations. Increased remote computations capacity will increase response capability i.e. the sophistication of the response and its timing. The entire system would be far less vulnerable to electromagnetic pulses.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Increased ability for parallel processing will be available with the development of appropriate parallel architecture.

   Increased ability to provide parametric information will be available with the development of this film sensor technology that can be incorporated directly.

   Increased ability to preselect (screen) large quantities of image information can be be constructed.

REPORTER: Bruce Steiner, NBS

AIDED BY:

TECHNOLOGY: Molecular-Scale Electronic Circuit Elements--Quantum Well Structures and Devices (G-3 [new version])

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Theoretical studies at University of Illinois and Arizona State University as well as MIT have indicated that a possible future generation of solid state devices is possible after the physical limitations of present micro-electronic logic gates has been reached at the very small submicron geometries predicted using lithographies below 0.1 microns. These new structures could generically be described as Quantum Well Structures. They exploit Quantum Mechanical behavior to eliminate the classic logic gate concept. Electron tunneling, two dimensional electron gas phenomena and ballistic transport will play major roles in these devices.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Group III-V compounds (i.e., GaAs) using molecular beam epitaxy (MBE) or other related deposition schemes are required to produce the high mobility materials initially needed to investigate these submicron structures' phenomena.

Alternative growth technologies--MO-CVD and LPE--need be developed for low cost processing. Etch and growth techniques which provide control of lateral dimensions with the required dimensions 0.1 microns and less need be developed as reliable, fast procedures. Given the high interface density and problems associated with contaminants it is likely that a unified dry processing fabrication technology will be necessary. Most of this technology is just now in the research laboratory--devices of ~10 nm lateral resolution have been fabricated as well as multilayer thin film devices with layer thicknesses of 2 nm--but only in the laboratory.

In situ optical monitors of the deposition/etching processes will likely be required for quality control.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Now in theoretical research stage--not until late 1990's or 2005.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

French, Japanese and USSR comparable to US research efforts.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

University research support is necessary to support this basic research.

Military needs must drive this technology in the sense that a whole new approach to electronics design is required. The development costs will be high. Without support from DoD and sixth generation computer programs the technology will languish. Once the technology is developed consum and commercial computer market places will benefit.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980	Co. State Univ. Univ. of Ill.
2. First Experimental Device Application (or first experimental process demonstration)	1986 -87	
3. When available for inclusion in product or process?	2005?	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

New laser frequencies, millimeter wave generators and other electro optical devices are possible fallouts from such research. Large random access memories appear feasible using structures below 0.1 microns. It is also likely that new approaches to our traditional electronics concepts will be supplanted.

B. To what products or processes might it be app'ied?

Millimeter wave sources and detectors; elect-: optical sources and detectors; new memory devices for high densit, data storage (i.e., >10M bit/chip)

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Large scale memory (high density RAM) greater than 10 Mbits per chip appear feasible.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Computer memory size will be vastly increased.

Growth techniques and QC techniques for growth process likely to impact other coating technologies such as those used for tribocoatings.

I would also expect that this technology will spin off completely unexpected new capabilities. Three dimensional device interconnects with high packing density will stimulate whole new approaches to information processing.

REPORTER: P.J. Boudreaux

AID Y: J.S. Murday

C^3

TECHNOLOGY: Macroelectronic Arrays (e.g. Flat Panel Displays, Electronic Tablets) [Concentrating on EL technology] (G-11)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Flat panel displays are approaching the point where they may become usable for a much wider variety of DoD applications. Current resolutions of plasma and electroluminescent (EL) displays are typically 60-80 lines per inch. Panels are single color. Plasma consumes hundreds of watts while EL consumes tens of watts or less in comparable size. Liquid crystals are a contender in non-projection single color form, but do not operate below 0° - 32° F. New EL technology promises multi-color, reasonably large area (8.5" × 8.5" to 1 m × 1 m), but advances in evaporation techniques, dopant uniformity and phosphor quality are required. Low impedance matrix drivers or transparent thin film transistor drivers deposited directly on the display are needed. Black background depositions allow EL to be viewed in full sunlight. Resolution over 120 lines per inch as well as multi-color panels are emerging.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Large, very pure evaporation techniques are required. Uniformity and thickness must be controlled to the micron or sub-micron level.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Small (~5" × 7") EL panels are available now. Multi-color panels may be available by 1990. 1 m × 1 m plasma is in prototype form now, but multi-color appears nearly impossible. 1 m × 1 m EL has not been successfully demonstrated in any form.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

The Japanese (SHARP) in conjunction with HYCOM in the US have produced small single-color EL panels successfully. The commercial market appears limited. US companies such as RCA and Magnavox are developing EL production lines. EL panels have already been introduced into the Army's Digital Message Device (a hand-held device used by forward observers and fire support teams).

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military needs are the drivers; i.e., visibility in sunlight; low weight--a few pounds for 8.5" × 8.5"; low power--- 100+ watts; operation over the full MIL SPEC temperature range. If the technology could be driven to a low enough cost, flat panel TV could finally result. Size, power, weight and environmentals are big pluses for military users. Multi-color is a commercial driver.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1984	ERADCOM & Contractors
2. First Experimental Device Application (or first experimental process demonstration)	1987	"
3. When available for inclusion in product or process?	1990	Dr. Elliot Schlam ET&D Lab Ft Monmouth

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

EL would be heavily used in tactical applications--smart terminals such as All Source Analysis System (ASAS), Tactical Computer System, etc. It could be used with any computer terminal requiring displays of 24 × 80 characters up to 1 m × 1 m with full graphics capability. Digital maps, ICONS, radar/aircraft tracks or text can be displayed. CECOM and ERADCOM have already replaced OC plasma panels with EL single color small displays in the Digital Message Device.

B. To what products or processes might it be applied?

Computer terminal displays from hand-held to large workstations.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Full color, high-resolution (>100 line/in) would give military commanders an unprecedented view of the battle scene (particularly at tactical levels) with digital map backgrounds allowing him to assimilate data quickly and produce more effective plans and decisions in a rapid fashion.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Combined with improved sensors, AI techniques for data fusion and planning, the US military would have a tremendous tool for acting within the decision cycle of the enemy and for "seeing deep" into the battlefield.

REPORTER: Joseph J. Pucilowski

AIDED BY:

C3

TECHNOLOGY: Satellite laser technology (J7/-12)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Space-based laser technology for communications requires space qualification, long lifetime, and for space-earth communications, powers on the order of 100 watts. For sea-water penetration, wavelength in blue-green range is required.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Both tube and solid-state technology have potential. Methods for obtaining lifetime and power combination in space have not been determined.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

wavelength demos--early 80s
power demos--early 80s all independent
lifetime demos--early 80s

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military needs

(1) blue-green sub comms
(2) high capacity, narrow beam (AJ applications)

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration SEE 2A		
2. First Experimental Device Application (or first experimental process demonstration)	1990	US
3. When available for inclusion in product or process?	1995	US

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Laser cross links for MILSTAR, SDI or Blue laser links to submarines.

B. To what products or processes might it be applied?

solid state laser array
antenna pointing technology

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

It could provide more secure, high data rate comms between satellites for comms or SDI C^3 applications. It would provide longer life laser transmitters for Blue laser comms to submarines at speed and depth.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Long life laser devices combined with new array technology and networking concepts would provide robust C^3 links for SDI sensor and battle stations or other satellite systems. These long life devices (either solid state or conventional) are essential for satellite to submarine links and will allow the subs to operate at greater speeds and depths.

REPORTER: J.B. Hughes (S&NWSC)

AIDED BY: C. Fuzak (NOSC)

TECHNOLOGY: Natural Language Understanding (NLU) (L-5)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Attempts in the 50's and 60's in NL processing using purely syntactic means (dictionary lookup of words, substitution and reordering of sentence syntax or matching sentences with libraries of meaning patterns) did not lead to much success. In the 70's Roger Schank introduced the concept of conceptual dependencies which arrives at meanings in terms of scripts within the context of discourse. In addition, with advances being made in parallel processing, researchers began to consider modeling NL systems as a set of interactive processes in which word meanings compete and reinforce one another within the context of discourse thereby eventually arriving at the most appropriate meaning. NL systems are usually characterized by the following metrics: 1) the level of misinterpretation that can be tolerated, 2) the level of training required by users, 3) the level of interactive verification of understanding that is permitted and 4) the size of the domain of discourse.

Given moderate goals (limited domain, some training, some verification and some errors) NL systems can and have been built today. These systems are also very limited in scope. For large vocabulary NL systems, a large knowledge base capable of increasing its knowledge through learning would be required. Problems of maintaining consistency in large knowledge bases and of acquiring innate knowledge (common sense) are considered to be the barriers.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

NL systems limited in scope exist today. With advances being made in parallel processing architectures, improved efficiencies would be achieved. However although the error rates, training required, and interactive verification requirements will all be reduced, these systems will still be limited in scope as to the size of the domain discourse.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

See 1B and 2D.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Research in NL is being performed in the U.S. by the University of Rochester, Illinois University, University of Pennsylvania, MIT, CMU, DARPA, U.S. Army CECOM, NRL and Cognitive Systems. Japan is also working in this arena.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Parallel processing architectures for NL systems.
Advances in maintaining consistency in large knowledge bases.
Techniques in learning.
Funding by DoD will drive it.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	CAPABILITY	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Limited	1984	U.S. DARPA CECOM Japan
	Large	1990	
2. First Experimental Device Application (or first experimental process demonstration)	Limited	1986	
	Large	1993	
3. When available for inclusion in product or process?	Limited	1989	
	Large	2000	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The understanding of information received as free text can be fused with other information to arrive at situation representation without having to first interpret the messages manually. NL systems can also be used in conjunction with speech systems to understand voice transmission.

B. To what products or processes might it be applied?

The five functional segments of command and control (fire support, maneuver control, air support, combat support and IEW). It can be utilized whenever free text is utilized to transfer information.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Could improve efficiency of information processing and understanding providing commanders relevant and current information allowing them to act within the enemy's decision cycle.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Combined with expert system technology (decision support systems) it could improve the effectiveness of command and control.

REPORTER: Dr. Martin Wolfe, U.S. Army/CECOM

AIDED BY:

C3

TECHNOLOGY: Development of Unmanned, Remotely Addressable Underwater Vehicles (L-10)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Technology exists for unmanned tethered underwater vehicles. Such vehicles are in use on the FBM submarines and are in advance development for tactical submarines. The vehicles are constrained to less than desirable launch, operating, and surviving speeds. Advancements in technology to improve hydrodynamic performance characteristics of unmanned underwater vehicles are required. In addition, technology advancements are required to provide additional/improved capabilities of the electronic payload (communication/navigation) of existing submarine towed buoys. Improvements in information transfer capabilities of the tow cable and antenna performance are particularly important. Alternatives to the existing multi-conductor tow cable should be explored. Fiber optics has been explored for tow cables with moderate success.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Batteries
VHSIC technology
Smooth, efficient tow bodies
Fiber optics
Acoustic communication links for system control

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Improvements to hydrodynamic performance capabilities (NRL/NSRDC/?) 1990

Improvements to communication/navigation capabilities (NRL/others) 1988-1995

Gould

Spears Associates

Magnavox

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Believe US is farther along in performance and sophistication than others working in submarine-towed communication buoys (England, France, USSR).

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need for submarines to communicate/navigate while on-station without compromising location or mission.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration Submarine-towed communication buoy	1959-1960	NRL
2. First Experimental Device Application (or first experimental process demonstration)	1959-1960	NRL
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- For communications to/from submarines to A/C and shore/other platforms.
- Surveillance and sensor relay.
- Air dropped or sub launched buoys for arctic warfare.

B. To what products or processes might it be app`'ed?

- Buoys (both towed and expendable)

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Allows subs to operate at speed and depth.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Integration of this buoy technology with VHSIC, new battery technology, fiber optics and streamlined tow body design will allow the military to operate submarines more efficiently, and provide numerous opportunities for new or better arctic operations.

REPORTER: J.B. Hughes (S&NWSC)

AIDED BY: Dale Lang (NRL)

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: TARGETED DELIVERY AND SUSTAINED RELEASE OF MATERIALS [A-4]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

It is now possible to incorporate a number of materials; e.g., drugs, toxins, hemoglobin, dyes into bags. Small micro dimensioned bags made up of lipids, polymerized lipids, and other non-biological polymers or surfactants Depending on conditions, the materials will leak or will not. Several groups have demonstrated the ability to decorate the 'bags' with antibodies leading to specific 'lysis' and leaking of encapsulants. In similar ways decorated 'bags' have been made which can be targeted to 'associate' with cancer cells or other targets at which time they can be made to break up and release their contents.

Besides targeted drug delivery, applications exist in high sensitivity detection, protective coatings, and prophylaxis .

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1) large scale encapsulation techniques must be achieved [filtration or counter current techniques]

2) leakage rates must be controllable and made specific

3) scale-up of 'antibody' must be achieved

4) stability of 'system' must be high or stability of the components must be high and system easily mixed

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Given large number of applications time line is broad. First products are now available. As immunological techniques and lipid rugged encapsulant techniques become more available, a large number of products also will result and have a major impact in 1995.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Japan is leader in this field in almost all aspects. US has had a good effort in medical applications--is only just starting to investigate non medical applications. Germany and France are also quite active in this field.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1977	Germany
2. First Experimental Device application (or first experimental process demonstration)	1979 1980 1981 1982	Japan England NIH, NRL U. of Texas
3. When available for inclusion in product or process?	Now--1995	"

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1) High sensitivity toxins, BW detector [10^{-15}]
→ determine success of decontamination

2) prophalaxis for CBW

3) protective clothing

4) protective films, paints [anti-barnacle film]

5) specific sustained release systems for parasites, other militarily important disease agents

B. To what products or processes might it be applied?

1) paints
2) epoxy's
3) chemical detectors
4) catalysis--chemical reactors
5) drug delivery techniques
6) anti-fungal treatment for clothing, people, buildings

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1) Decrease maintenance of ships; equipment, etc.
Increase long term efficiency of fleet, buildings, equipment.

2) Decreased risk to CBW.

3) Significantly improved jungle effectiveness.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

1) Combined with other breakthroughs in advanced biomaterial technology effective protective clothing against most toxins and bacterial agents can be envisioned.

2) Novel synthetic techniques may lead to better fuel cells and energy systems: therefore better 'closed' life support systems

3) More effective treatment of personnel against infectious diseases

4) Artificial skin?

REPORTER: Joel Schnur

AIDED BY:

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: DEVELOPMENT OF ORGANISMS THAT DEGRADE MILITARILY RELEVANT PRODUCTS [A-5]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Genetic engineering techniques have demonstrated the potential for custom-design of bacterial strains to metabolize harmful compounds to less harmful or neutral compounds. Such technology will provide the means for significant improvement in protection of personnel and environments that would potentially be exposed to toxic compounds. Such custom-designed microorganisms could also be useful for metabolizing parent compounds to reduced forms that include militarily significant materials.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Although the fundamental techniques involved in transfer of genetic material have been worked out and proven effective in creating novel bacteria capable of efficiently metabolizing specific compounds (such as phenols) in the laboratory, major problems remain in terms of scale-up from laboratory to field or industrial operations. Further work is required in the areas of batch culture, regulation of substrate feed, and collection of metabolized products which one desires to keep. Release of organisms into environment poses potential environmental problems in terms of mutated organisms.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

1990--or later depending on the specific substrate or product.

B. **Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.**

The US is the current leader in this field of biotechnology. Other work is on-going in Western Europe. A strain of Pseudomonas that efficiently degrades toxic phenolics to non-toxic products is currently being field-tested at several USAF bases. Not aware of Warsaw-Pact efforts in this area.

C. **What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

This technology will be driven by the need to eliminate toxic products and to produce scarce materials. In the industrial/consumer sector the cost of the technology will be the driver, but in the military sector, the need for a "clean" operating environment in confined cabins as well as the need for production of scarce materials will be a stronger driver than cost per se.

D. **Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.**

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975	US
2. First Experimental Device application (or first experimental process demonstration)	1983	US AFESC
3. When available for inclusion in product or process?	1990	US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1) To degrade toxic compounds to less toxic products for environmental protection both in confined cabins and the external environment in which the military operates.

2) Production of scarce materials of military significance.

B. To what products or processes might it be applied?

1) waste-treatment
2) life-support systems
3) detoxification/decontamination
4) production of scarce, but militarily significant materials

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Development of this technology will permit the military to operate in previously contaminated environments. It will provide new life support system capabilities by removal of toxics from confined environments, or production of needed life support substrates such as O_2, etc.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Could provide novel detoxification/decontamination capabilities for chemical warfare environments when combined with current approaches at detox/decon not utilizing microbial metabolism.

REPORTER: Joel Schnur

AIDED BY:

TECHNOLOGY: DEVELOPMENT OF ORGANISMS THAT WILL COUNTER BIODEGRADATION OF MATERIALS [A-6]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

1) The organisms responsible for biofouling (macro & micro) have been identified.
2) The organisms causing biocorrosion are known particularly those that grow at high temperatures.
3) The genetics of some of the micro-organisms are known which permits an understandi of the process of biodegradation at a molecular level.
4) Enough basic information is available to begin to design chemicals, or biological molecules to inhibit biodegradation.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1) Production of point-mutations to alter genetic information.
2) Equipment to selectively release biological organisms to prevent biodegradation and/or biofouling.
3) Equipment or techniques that either destroys or contains organisms used to control unwanted organisms.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

From between 1990-95 depends on understanding control of immune systems.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US comparable to France and Swiss

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1979	Simon Colwell Mitchell
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?	1995	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Combat environment simulation technology would be used to provide realistic simulations of combat to: train and test individual, team, and unit proficiency in use of combat skills; test operational material under combat-like conditions; develop and evaluate tactical doctrine in high-fidelity combat environments; train, test, and provide refreshe experiences for command and staff.

B. To what products or processes might it be applied?

The major application would be to improve the combat effectiveness of personnel, units, doctrine, and materiel.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. See 3.A.

2. In addition, training costs of military services would be reduced by a significant order of magnitude.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Joseph Ward

AIDED BY: Earl Alluisi

MISSION SUPPORT (PERSONNEL, TRAINING, HUMAN FACTORS)

TECHNOLOGY: COMBAT ENVIRONMENT SIMULATION TECHNOLOGY Rank 7 or 8 (new)

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The defense establishment has always been hampered by a lack of a realistic combat environment for validly determining the effectiveness of its combat operations. Determining whether changes in individual skill proficiency, tactical employment doctrine unit size and composition, operations capability or weapons and equipment, command and staff training, and interrelationships among units resulted in improved combat effectiveness or not was based on data derived from low fidelity simulations of combat environments. Individual combat skills training lacked the realism of performing under fire; opposing forces exercises lacked the realism of immediate feedback of casualties; command and staff training exercises were inordinately expensive, infrequently conducted, and lacked the realism of real time pressures, material expenditures, and combat conditions; training exercises lacked the realism inherent in a "live" enemy shooting back. A new technology is emerging to provide realistic simulations of combat for training and testing purposes. Combat simulation technology is a combination of emerging technologies involving lasers, rapid information processing, interactive computers, graphic imagery, visual displays, helmet-mounted displays, and AI-based combat protocols. Applications of some combinations of these technologies have already produced realistic combat environments which permit immediate feedback of hit/kill ratios for opposing forces. Expanding and improving the technology to provide increased

(cont'd below)

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The technologies necessary to provide realistic combat environments for the armed services are currently available for low fidelity simulations. Research on these technologies and their effective combinations to provide high fidelity combat environments needs to be expanded. The fact that successful simulations already exist indicates that implementation could be accomplished in a relatively short time frame.

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1. A. (cont'd) high fidelity is a critical requirement at this time.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Research by the Army Research Institute developed the MILES laser-based training system now being used for tactical training. Technology is being improved and expanded to other weapons systems. Using this technology in combination with computer information processing techniques, graphic simulation and AI combat protocols would enable battalion sized opposing forces exercises to be conducted under near combat-like conditions. Increasingly sophisticated gaming simulations provide mastery training in command and

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US lead is substantial.

2. A. (cont'd) staff functions. Flight simulations are becoming increasingly sophisticated and effective aids to combat training through the application of graphic imagery and AI. These technologies must be expanded to provide service personnel opportunities to acquire and maintain their combat skills. High fidelity simulations of combat would be available within 4 years.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

1. Need for valid information on effectiveness of personnel, materiel, and doctrine.
2. Need for more cost effective combat training and practice exercises.
3. Need to reduce high cost of training and combat exercises.
4. Need to increase realism of training.
5. Need to increase practice exercises of individuals, teams, units, and staffs.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1986	Army, Navy, Air Force, Human Resources Research Labs
2. First Experimental Device application (or first experimental process demonstration)	1990	"
3. When available for inclusion in product or process?	cont'ing	Army, Navy, Air Force

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

CAD man-machine interface job design should be used in system conceptualization and development for every new US military system where human operator and maintenance performance is essential to system effectiveness. Further, it can be used to improve system/equipment modification rapidly.

B. To what products or processes might it be applied?

Wherever humans are used to operate and/or maintain military systems (at any level of sophistication and complexity), CAD techniques of this type can (and should be) applied.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The following impacts are anticipated from CAD technology in military system design:

1. Better job-person matches resulting in improved job performance and enhanced job satisfaction

2. Reduced skill and training requirements particularly for critical military skill categories

3. Better anticipation of future military manpower demands so that supply can meet demand

4. Reduced system design costs and operational life cycle costs.

8. What synergistic effects might this technology have on US military capabilities wnen combined with other technologies?

This technology is concerned with the lead driver (job design) for all military manpow personnel, and training problems in subsequent operational systems. To the extent that job-person matches can be optimized, future MPT problems will be reduced. This application is, in fact, a combination of several hitherto separate human factors and MPT technologies. Further, better human performance should improve operational readings and effectiveness in such technology areas as command, control, and communications, robotics, automation, machine intelligence, and human computer interfaces. Advanced CAD systems of this type will eventually incorporate expert systems.

REPORTER: Fred Muckler

AIDED BY:

TECHNOLOGY: COMPUTER-AIDED DESIGN (CAD) FOR OPTIMIZED MAN-MACHINE INTERFACES AND SYSTEM MANPOWER, PERSONNEL AND TRAINING Rank 6 of 8 [New]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Good man-machine interface design very early in system conceptualization and development is essential to optimize operator and maintainer performance and minimize operational manpower, personnel and training (MPT) problems. CAD techniques are emerging that allow conceptual design alternatives to be generated in 20 minutes as opposed to 8 or more hours by manual drafting. Further, the CAD systems generate quantitative data for (1) operator and maintainer performance predictions, (2) man-machine function tradeoffs, (3) anticipated skill and training requirements, and (4) predicted life-cycle demand on future manpower supply by military occupational specialties.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Demonstration CAD systems for man-machine interface design are already in operation in the US and Europe (England, Sweden, and Germany). Alternative, detailed, physical job layouts can be produced in minutes, evaluated, and re-design accomplished immediately. The present CAD systems differ in the relative ability of their software algorithms to generate quantitative predictions of MPT dimensions.. In decreasing sophistication (i.e., reliability, validity, precision, and usability), the current state of the art is (1) strongest in operator and maintainer performance predictions, (2) good in man-machine function tradeoffs, (3) fair in life-cycle manpower predictions, and (4) weakest in anticipating skill and training requirements. On the last, there are several systems under development in research laboratories and particularly in nuclear power system design. The full power of CAD here demands extensive, and lengthy, algorithm development.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

The technology is available now for several specific and limited applications but 5-10 years are needed for (1) more system area applications and (2) improved MPT algorithm development.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

Non-US work (England, Germany, Sweden, and Japan) is proceeding rapidly principally in the area of commercial systems. The CAD technology is not spreading as fast in US design engineering. But the US technology base in CAD algorithm development is considerably advanced over non-US systems.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

In the commercial area, consumer sales and satisfaction is driving the application of this technology in human factors. In military US system design, operational manpower and training problems are feeding back to system design demanding less complex job designs and reduced MPT requirements. Users are insisting that these problems will decrease in future.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1973 - 1975	US NADC HRL
2. First Experimental Device application (or first experimental process demonstration)	1980	US NADC
3. When available for inclusion in product or process?	1995	US Germany England Sweden

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Training and job aiding may be used in almost any operational system for both initial or refresher training--or in the case of job aiding--for performance enhancement. The military could benefit primarily from embedded user manuals, and interactive training and aiding for operators and maintainers of weapon systems.

B. To what products or processes might it be applied?

A good example of this technology may be seen in one facet of radar operations applicable to all services, i.e., Electronic Counter Measure (ECM) or jamming recognition. This is a skill that is rarely practiced in peacetime, is treated inadequately in the schools because of the dynamic characteristics of ECM (static pictures are used), and is very poorly retained. Embedded training could be used to assess the state of the users knowledge, and to provide training and performance feedback on a regular basis.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Results of battle exercises are a continual reminder that personnel are not adequately trained in combat related skills, and that readiness can be improved. This technology offers enhanced readiness through on-going performance assessment and refresher training; as well as realistic, interactive training for teams and individuals

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Alice Crawford

AIDED BY:

MISSION SUPPORT (PERSONNEL, TRAINING, HUMAN FACTORS)

TECHNOLOGY: EMBEDDED SYSTEMS FOR TRAINING AND JOB AIDING Rank 5 of 8 (new)

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The technology consists of training (instruction, drill and practice, performance testing and feedback) or job aids built into systems used on the job. Such systems span the range of job skills from on-line tutorials in administrative systems, to simulation of performance on operational equipment.

Historically, traditional and computer-based training has been delivered in the school house; cost and manning factors constrain the frequency and duration of school house tours. As a result, maintenance of combat related skills is often inadequate. Embedded training, in conjunction with technologies in cognitive ability measurement and performance assessment, can provide refresher training on-the-job in amounts and intervals determined necessary for job ratings or individuals. It represents a dual purpose use of one system.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Instructional development must take place with system design with the end product a result of input from both engineers and training experts.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Embedded training technology is available for demonstration.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Developmental work has been completed demonstrating cost effectiveness of embedded training. The US Army Research Institute program (TOS/TACFIRE) demonstrated embedded training as a viable technology for including instruction as an integral part of a system.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Most embedded training applications have been limited to programs that might be characterized as helping the learner to operate the equipment of which the computer is a part, or the computer itself. This training is relatively quick and inexpensive. Programs that involve full instructional illustrations, color and more complex analysis with feedback sequences have been demonstrated. Much commercial software now being marketed for personal computers includes introductory tutorials as part of the product.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1982	ARI
2. First Experimental Device application (or first experimental process demonstration)	1984	ARI, IBM
3. When available for inclusion in product or process?	1988	Military

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Selection, classification, training, and assignment of personnel will be substantially improved by accounting for information-processing speed abilities/aptitudes that have been matched to task/job requirements for information-processing speed (in addition to level) skills. A testing battery, administered by micro-computer or computer terminal, would yield measures of the traditional in addition to the newly identified abilities/aptitude.

B. To what products or processes might it be applied?

(1) Jobs/tasks analyzed in terms of traditional and newly identified skills
(2) Military manpower & personnel systems
(MOS, AFSC, Rating) changes

(4) Design of tasks/ Jobs in military systems

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The optimum use to the human operators, maintenance, and supporters of the U.S. weapon systems will provide a most cost-effective means of maximizing the effectiveness multiplier by ensuring that every force has the mix of human skills appropriately distributed to realize fully the design capabilities of its assigned weapon systems in actual operations.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

In addition, manpower and training requirements would tend to be lowered by the more effective and efficient use of the organic (human) component.

REPORTER: Earl Alluisi

AIDED BY:

MISSION SUPPORT (PERSONNEL, TRAINING, HUMAN FACTORS)

TECHNOLOGY: COGNITIVE ABILITIES/APTITUDE MEASUREMENT AND PERFORMANCE PREDICTION/ASSESSMENT(N) Rank 4 of 8 (new)

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Conceptual advantages in cognitive psychology, coupled with computerized testing capabilities, have led to the identification of human abilities and aptitudes heretofore ignored. For example, information-handling speed factors that are esentially independent of the traditionally tested verbal, quantitative, and reasoning ability/aptitude-level factors have been identified. The three speed factors have reliabilities, and validities comparable to the level factors (e.g. $\sim$.40 to .60), and appear to predict performance especially well in high-information-flow conditions where speed of information processing could be expected to play important roles (e.g., factors $\sim$.20 in low information-flow condition to $\sim$.80 in high information-flow conditions).

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The basic theory and models are in place or could be realized in about a year for the testing of the ability measures. About two years (parallel) would be needed to gather the data and validate their use as aptitude measures. About three years (parallel) would be needed to develop, test, and validate techniques for analyzing tasks and jobs in terms of their information processing speed (as well as level) skill requirements. Finally, about four to six years (six parallel, four serially following the aptitude-measure development) would be necessary to construct performance assessment techniques based on these new technologies with surrogate performance tests.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technology demonstration within 5 to 6 years.
Full-scale implementation within 10 to 12 years.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

U.S.A. has the technological lead in the area at present. Coordinated R & D at the Service MPT laboratories (AFHRL, ARI, & NPRDC), and supporting scientific research (ONR, AFOSR, ARI), have given the U.S.A. a 5 to 10 year lead.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Opportunity: (1) Advances in cognitive psychology and theory
(2) Applicability of microcomputers to testing

Needs: (1) Changing nature & mix of military tasks and jobs (increasing importance of speed in decision-making and action in operational as well as maintenance positions at all levels).
(2) Manpower constraints that force greater efficiency.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1984	US AFHRL
2. First Experimental Device application (or first experimental process demonstration)	1985	US
3. When available for inclusion in product or process? (spinoff of components earlier)	1990-92	US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1) The helmet mounted display systems are scheduled for use in high fidelity. State-of-the-art flight simulators, capable of performing a variety of combat/operational mission senarios. (Included are high resolution high brightness and high contrast color projectors)
2) The requirements for sensor simulation and coordination (i.e., CGSI) are generic across many platforms, including aircraft, and surface and subsurface ships and ground installations.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The helmet mounted laser projection system will provide increased visual fidelity via monochromatic one-channel CIG display with an instantaneous narrow field of view simulating an inset high resolution area of interest (AoI). It is anticipated that the display will have an observer-apparent performance double that of existing display systems at about one-third the production costs. AF vs AFHRL, fiber optics and high resolution display technologies are being coupled with helmet mounted display technologies in the attempt to develop and affordable combat mission trainer for use by operating wings and squandrons.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Alfred Smode (NTEC)

AIDED BY: Earl Alluisi (AFHRL)

TECHNOLOGY: IMAGE GENERATION/DISPLAY

Rank 3 of 8 [New]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The growing reliance on simulation to support training in military tasks has generated the need to extend the relevance of instructional systems capabilities. The efforts include investigations into improved simulation capabilities in areas to image generation, visual/sensor displays and the simulation of specialized training environments in support of all warfare areas. While extensive gains have been achieved in Computer Image Generation (CIG), current capabilities fall short of what is needed for the full range of visual display and simulation in military training. On-line techniques for providing wide angle high brightness, high contrast, high resolution visual presentations in a simulator are very costly, and tasks requiring high scene detail at close range and those with dynamically changing visual content caused by object motion or surface effects are difficult to simulate. Limitations in hardware and Data Base Technology are major problems as is the high relative cost of such simulators for use in multiple-copy training settings.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1) Potential solutions based upon advances in diverse technologies such as (a) Helmet mounted displays (laser projector; fiber optics; or miniature CRTs); (b) area of interest (AoI) high resolution inserts or variable acuity lenses; and (c) high intensity color projectors, show substantial promise.

2) New operational target acquisition/weapons delivery suites are designed to receive and correlate data from a variety of sensor sources. Sensor imagery is novel to observer and is more difficult to use and interpret. A major goal, therefore, is to develop techniques for simulating advanced sensors for training devices. The thrust is to develop a broad spectrum of alternative solutions to the problem of sensor simulation and coordination. Several emerging technologies are promising. For example, a hybrid approach to sensor simulation based on computer generated/synthesized imagery (CGSI) is under development at NTEC. Another hybrid technique is cell texturing under development by G.E. (for AFHRL, PM trade).

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1) All three helmet mounted displays, as well as AoI inserts, variable acuity lenses and both liquid and solid crystal color projectors have pursued proof-of-principle stages, but none have been developed to the technology documentation phase. All have strengths and weaknesses.
2) NTEC is currently developing specifications for CGSI where the primary issue concerns the feasibility of real-time CGSI for high data rate low-altitude flight profile visual/

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

2.A. cont'd

sensor displays. Currently, multi-spectral sensors for low altitude missions cannot be effectively simulated. Cell texturing technology has been demonstrated in the Air Force/Army AVTS system, developed by G.E. The full potential of the system has yet to be exploited.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	HMD	1982	NTEC
	CGSI	1987	
2. First Experimental Device application (or first experimental process demonstration)	HMD	1986	NTEC
	CGSI	1988	
3. When available for inclusion in product or process?	HMD	1990	NTEC
	CGSI	1990-95	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Potential military applications include individual decision aids for specific decision problems, e.g. estimating target range from multiple estimates with different error characteristics; and for multi-person decision hierarchies such as C^2 in Navy Battle Groups or Battle Forces at a tactical level and Area/Fleet Commands at the strategic level.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Effectiveness (quality and timeliness) of command decision-making will become the critical determinant of military success; which side can best manage its resources; hardware will eventually achieve a parity if not already.

The synergistic effects of this technology are to effectively coordinate surveillance, weapons and decisions at lower levels for maximum force application.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Willard Vaughn

AIDED BY: Fred Muckler

MISSION SUPPORT (PERSONNEL, TRAINING, HUMAN FACTORS)

TECHNOLOGY: DECISION AIDING SYSTEMS Rank 2 of 8

[Delphi Adaptation]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Decision aiding systems of the future will depend on two interrelated emerging technologies: The evolution of AI-based intelligent capabilities of computer systems and interactive, human-computer interface design concepts that enable efficient dialogue and effective aggregation of human and machine intelligence.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Main technological developments required to bring about this class of decision aids include knowledge representations, interactive languages and dialogue control mechanisms that enable interactive decisionmaking between the human and the intelligent system. A major area of application will be to multi-person decision-making teams supported by distributed knowledge bases and computational facilities. These systems will require technological development of distributed algorithms for process control and reconfiguration.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

-individual decision makers; 1995

- distributed decision teams, 2000

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Application of AI and computer science technology to decision making systems is mainly a U.S. and U.K. enterprise. In the U.S., MIT, Stanford, Yale, CMU, etc.; in the UK, The Turing Institute, University of Endinborough.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- Need for timely, high quality decision-making in fast-tempo military engagements, i.e. strategic defense.

- Increasing complexity of decision environments and need to decompose and decentralize decision authority without loss of coherence.

- Military development concepts that geographically distribute elements of a force.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	individual multi-person	1985 1990	US US
2. First Experimental Device application (or first experimental process demonstration)	individual multi-person	1990 1995	US US
3. When available for inclusion in product or process?	individual multi-person	1995 2000	US US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The principle use of ICAI technology is in the development of automated individualized instructional systems. The major features of such systems are that they can: (1) monitor student performance, inferring knowledge from his actions; (2) evaluate student progress by comparing his knowledge with that of an expert and with an "ideal" student; (3) diagnose the conceptual "bugs" in the students' understanding; and (4) control the sequencing of instruction, providing remediation where necessary.

B. To what products or processes might it be applied?

This technology would have applicability in a wide variety of instructional contexts, including (but not limited to) the teaching of: basic skills, complex procedural tasks, maintenance and troubleshooting, team training, and expert systems.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The military impact of this technology is to greatly increase the efficiency and effectiveness of training by leveraging the role of the human instructor, in effect increasing the instructor/student ratio. The result would be a better-trained force at lower cost.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Stan Collyer

AIDED BY:

MISSION SUPPORT (PERSONNEL, TRAINING, HUMAN FACTORS)

TECHNOLOGY: INTELLIGENT COMPUTER-AIDED INSTRUCTION (ICAI)

Rank 1 of 8 [Delphi Adaptation]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

To date computer-aided instructional technology has generally failed to live up to its promise largely because most CAI systems have been little more than automated page-turners, with relatively simple branching algorithms. Intelligent CAI systems, however, have the potential for a far greater impact. Such systems would closely emulate the behavior of experienced instructors who possess a deep understanding not only of the subject matter but also of the cognitive processes underlying efficient learning, pitfalls commonly encountered by students learning that material, proper remediation techniques, etc.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

In order for ICAI to become a practical reality, expert systems must be developed that emulate:

(a) a subject-matter expert with extensive domain knowledge;
(b) a student whose knowledge becomes increasingly less primitive; and
(c) a tutor, possessing knowledge of good instructional principles and techniques.

In addition, advances are needed in the areas of knowledge acquisition and design of human-computer interfaces in order to facilitate the transfer of knowledge from experts to expert systems.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

First-generation systems within five years.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US presently has a clear lead.

C. What needs/opportunities will drive this technology (e.g., costs, military, *industrial, consumer, environmental, etc.)? Be as specific as possible.*

This technology is driven by the high cost of training, and the number of people in the training "pipeline" at any given time. For example, Navy spends approximately $9 billion each year; 25% of the force is involved in training at any time.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985	
2. First Experimental Device application (or first experimental process demonstration)	1990	
3. When available for inclusion in product or process?	2000	

8. What synergistic effects might this technology have on US military capabilities when combined wit. other technologies?

REPORTER: Willard Vaughn

AIDED BY: Fred Muckler

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Remote/Robotic devices have principal applications for environments of particular hazard to humans: outer-space, undersea, biological/chemical/nuclear warfare environment. Generic military functions of surveillance and weapon delivery are their principal uses.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Remote robotic devices, such as can be envisioned as emerging from the integration of these technologies, would give the US military important tactical advantage in that hazardous/lethal/inaccessible environments could be penetrated for military purpose.

Successful development of these devices will revolutionize the nature of human work and bring about a remotely controlled battefield; but they require the expansions in the sensing, control and manipulation technologies described here.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Estimate of time available for image recognition systems: 1990, for visual input; 1995, for haptic input (touch and manipulations)

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Estimate of US status: The basic technologies are principally US and Japanese.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- Industrial production systems i.e., the automated factory of the future. National Bureau of Standards Manufacturing Laboratory.

- Exploration systems: e.g., undersea surface exploration/charting core-sampling for minerals, etc.

- Military potential for remotely operated surveillance and weapons systems in hostile environments.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. **Proof of scientific principle demonstration**: Image recognition, Voice I/O, Supervisory Control, Haptic Manipulation	1985	--
Same as D. 1. 2. **First Experimental Device application (or first experimental process demonstration)**	1990	--
Same as D. 1. 3. **When available for inclusion in product or process?**	1995	--

TECHNOLOGY: SENSING, CONTROL AND MANIPULATION TECHNOLOGIES FOR REMOTE/ROBOTIC DEVICES Rank 8 of 8 (Delphi adaptation)

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Successful development of effective remote/robotic devices requires the integration of several emerging technologies; principally, image recognition from both vision and touch systems, supervisory control of the device by human operator/controller, speech input/output for control input and feedback, and end-effector, manipulation device technologies.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The research foundations for these emerging technologies are at various stages of development and will require differential emphasis to bring their integration to a useable stage. Image recognition by visual processing algorithms is most advanced, having benefitted by extensive interest in the research community and funding agencies. Image recognition from touch and manipulation of objects, by contrast, is less-well understood but important for application environments that exclude vision as input modality. Remotely controlled devices require a computer-based control system that links the device to the human operator. Research foundations in this area have developed to the stage of permitting experimental implementation in underwater vehicle/manipulator systems. Device control is distributed between a local computer and a remote computer interfaced to the human controller. Emerging technology in this area is toward more sophisticated software that enables adaptive control, i.e., the local computer learns from experience with the remote control computer. A potential I/O channel for command and feedback in supervisory control systems is voice. Speech recognition technology has reached the stage of one-user, limited vocabulary, one-word-at-a-time capability. Semantic speech models for proscribed content domain are needed to bring this technology to a useful stage. End-effector development is bringing about sophisticated hands with a variety of sensor components and compliant grasping and manipulations capabilities. This technology is modelling the anatomy of the human hand and eventually will need to incorporate knowledge about how touch information is processed in sensing and manipulating functions.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

NA

REPORTER: James Vorosmarti

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The treament of any combat casualty in which skin loss occurs. May also be applicable as a general wound covering.

B. To what products or processes might it be applied?

NA

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Will allow saving of lives, reduction of medical personnel for care of these patients and in some cases earlier return to duty, decrease logistics burden.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

After 1990

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Probably equal to France . No other work known.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The drive for this now is the poor survival rate of severely burned patients and the cost of medically treating burned patients.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1982	US/France
2. First Experimental Device application (or first experimental process demonstration)	1983	US
3. When available for inclusion in product or process?	after 1990	

TECHNOLOGY: ARTIFICIAL SKIN DEVELOPMENT [New]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The survival of patients with more than 50% body surface burns is almost nil because of lack of appropriate dressings. The development of artificial skin should allow most of these patients to survive as well as reduce the nursing requirements for any patients with burns or skin loss. The requirements for blood and blood components and intravenous fluids will be decreased relieving the logistics burden particularly for blood.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Production techniques must be developed for large scale production

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Robert Newburgh

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Production of strategic materials
2. Production of products not available through other techniques.

B. To what products or processes might it be applied?

New chemicals or biochemicals
Enzyme catalysis with hydrocarbons

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Only in terms of producing new compounds for military use.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Probably not until 1995

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Not known.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need for cheaper or different materials in military or non-military markets.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1984	?
2. First Experimental Device application (or first experimental process demonstration)	1990	Genetic Engr firms
3. When available for inclusion in product or process?	1995	Monsanto

TECHNOLOGY: ENZYME CATALYSTS THAT WORK IN NON-AQUEOUS ENVIRONMENTS [3-9]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

1. Ability to conduct enzyme catalysis in organic solvents has been demonstrated.

2. The small scale use has been demonstrated and it is now time to move into large scale production.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Bioreactors
2. Methods for stabilizing or modifying enzymes for specific purposes.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: ______________________

AIDED BY: ______________________

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

--Protective clothing
--Removal of toxins from confined environments
--Generate search/complex military relevant materials via catalysis, sideproducts and inhibition.

B. To what products or processes might it be applied?

Any manufacturing processes involving generation of specified products requiring enzymes. Certainly could be used to meet safety air quality standards in industrial work places. Continuous chemical synthesis, catalysis for transformation of hydrocarbons and for detoxification. Organic synthesis at industry-wide range.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Increase survivability in CW and other toxic environments.
Increase capability of making militarily useful compounds or materials.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Duke Marine Labs has immobilized acetylcholinesterase in small pilot study as described in 1-A. Estimated time for use in a filter is still 5-10 years away--Also a more generic enzyme is needed.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Not known by this panel.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The generation of large amounts of products based upon complex enzyme reactions are good candidates.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975 1982 1984	Hofmann & [illegible] Dupont, NIA Duke Marine Labs
2. First Experimental Device application (or first experimental process demonstration)	1985	"
3. When available for inclusion in product or process?	> 1990	

TECHNOLOGY: BIO-CATALYSIS WITH IMMOBILIZED ENZYMES [B-5]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

This technology involves immobilization of enzymes to a solid matrix to enhance the substrate enzyme interaction and to allow rapid separation of the products from the matrix for either release to the environment or collection. Several enzymes have been immobilized but militarily, those capable of inactivating chemical agents in a generic sense are highly desirable. Acetylcholinesterase has been immobilized in a carbon fiber matrix and in preliminary studies has been shown to breakdown over 99% of chemical nerve agents simulants in air passed over the bed for up to 24 hours. Filters with immobilized enzymes have high specificities, require infrequent replacement and inactivate rather than trap agents.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Need to have ability to immobilize enzymes that can remain active in adverse i.e., non-aqueous, environments. Also have to define the immobilization process such that enzyme activity is not compromised particularly in large scale, continuous operations. Immobilization in wide variety of substances still needs work. Others? Not sure of examples--for manufacturing processes.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Overall improved survivability and effectiveness of human exposed to potentially hostile environments.

REPORTER: Prociv

AIDED BY: E. M. Andrysick

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

as a dosimeter (1) to determine threshold dose, or when an individual soldier is close to exceeding an operational dose

(2) to determine if materials in space may be off-gasing a toxic gas and what dose

(3) ditto for submarines

B. To what products or processes might it be applied?

1. Infantry soldier
2. pilots of low and high perf. aircraft
3. Space station
4. SDI defenses (identification of energy, etc.)
5. life support systems (for trace containment, toxic buildups; method for early warning and detection)

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Would improve the useful longevity of the fighting soldier, pilot, submariner, etc. By pulling individuals off-line from toxic environments, their body would be given the appropriate time to detoxify the sub-effect levels before returning to the toxic environment
- bio reactor applications

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1. DoE/Pacific Northwest Laboratories have demonstrated technology for commercial chemical (now)
2. glucose oxidose--for fermentation detectors (now)
3. protein incorporation into artificial environments (now)

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

No non-US work known.
Japan, USSR have basic research programs in these areas; USSR program has worked extensively with bacterial rhodopsin (mid 70's)

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

--military operational advantage (CBR environments)
--increased survivability
--industrial interest (mining, chemical)

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

Key: 1,2,3 same as 2.A. (above)

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1. done 2. 1970 3. 1970s	PNL * Singer NRL, Ger., Eastman Koda-
2. First Experimental Device application (or first experimental process demonstration)	1987	CRDC
3. When available for inclusion in product or process?	1990	Industry

TECHNOLOGY: BIOSENSORS FOR IMPARTING SPECIFICITY [A-11]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Dosimetry based on immobilized bacteria, genetically engineered to release materials when stressed. Materials can be detected by a variety of means (fluorescense, conductivity, etc.). Chemical dosimeter can improve survivability in NBC environments & space submarine atmospheres by early warning of accumulated dose. Estimate a 60-80% survivability.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

--Encapsulation/immobilization of bacteria
--Replacement of bacteria through monoclonal antibody/conjugates technology

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

If combined with techniques that diminish the effects of stress on the immune system, one may see a decrease in debilitating disease. (Behavioral Immunology and Immunological Defense)

REPORTER: Robert Newburgh

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Treatment of viral and immune diseases and other infectious diseases
Treatment of military personnel exposed to Bio agents.
Restore repressed immune function.

B. To what products or processes might it be applied?

Production of proteins or peptides that enhance the immune response.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Diminish days lost due to common viral infections.
Diminish casualties from B. W. agents
Diminish lost days that result in increased disease due to repression of immune system
that occurs as a result of stress.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Products and production processes are already available. Clinical trials and isolation of new compounds will require approx. 10 years.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US significantly ahead.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The need to diminish days lost due to viral diseases in military.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980	Several
2. First Experimental Device application (or first experimental process demonstration)	1982	Several genetic Eng. Co.'s
3. When available for inclusion in product or	1995	

TECHNOLOGY: MATERIALS FOR CONTROL OF HUMAN IMMUNE RESPONSE FA-37

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The lack of clinical studies and specific compounds to enhance the immune response has limited the development or control of the immune system. This is particularly true for enhancement. It is now possible to use recombinant DNA techniques to produce peptides (e.g., Interleukins, interferons) that are known to enhance the immune respons The scientific principle of controlling the immune response with known naturally occur compounds is established. The current need is to identify and characterize the key proteins or peptides. These likely number less than a dozen. The judicious use of these compounds requires a better understanding of the immune system, its role in diseas states, and the characterization of histocompatibility of antigens and receptors. The use of these compounds requires FDA approval which means clinical testing. This is a long process and will require a time frame of at least five years.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The production of proteins or peptides by recombinant DNA techniques is well established Interferon was one of the earliest products produced. One needs to isolate and charac terize the proteins or peptides and genes involved. A critical requirement will be scale up for cost effectiveness.

The keystone equipment are containment facilities, chromatography, and scaled up grow chambers or bioreactors.

The materials are living organisms such as vectors (plasmids, viruses), the required genes that can be amplified and the proper bacterial host.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Scale up problems are similar to other encapsulation and bio fluid technologies: solution will have positive effect on all related technologies.

REPORTER: Joel Schnur

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Battlefield, shipboard casualty care
Emergency field hospital blood supply
Perfusion of organs
Therapeutic treatment of blood linked diseases (jungle environments, warfare)

B. To what products or processes might it be applied?

All short term situations where oxygen carrying fluids are needed to sustain life.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. Decrease in deaths related to bleeding, shock, etc.
2. Increase in rate of return to effectiveness of personnel.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

N.B.7 year approval time required for FDA. (see note at 1 above)

approx. 1995

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Japan and France are very active in this area along with US.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible

Blood supply is likely to be infected by AIDs, hepatitis
casualty care fluid is only being driven by DoD funding and requirements
an artificial oxygen carrying replacement fluid is achievable within a decade if DoD provides adequate 6.2-6.4 funds in next 5 years.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1979 1975	NRL (LEH) Fran U. Chicago Japan
2. First Experimental Device application (or first experimental process demonstration)	1984 1980 (fluorocarbon)	NRL/U. Chicago NIH
3. When available for inclusion in product or	1988	start trials

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: BLOOD SURROGATES FOR UNIVERSAL TRANSFUSABILITY: REPLACEMENT OXYGEN CARRIER FLUID* [A-1]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Several alternative approaches now exist, which, if successful will lend to typeless, easily stored oxygen carrying fluids. These include:

1. Enzymatic cleavage for universal donor
2. Liposome encapsulated hemoglobin
3. Modified, concentrated hemoglobin
4. Fluorocarbon based fluid (not good for battlefield)

If available such fluids could, in battlefield conditions, significantly (approx. 50% reduction) decrease casualty mortality. Other applications exist for civilian purposes, e.g., casualty care of automobile accident victims.

* This is not an artificial blood.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Liposome Encapsulation:
1) large amounts of 'spent' hemoglobin exist
2) large scale lipid separation equipment will be required
3) sterile preparative facilities for preparation and storage
4) non-filtration based encapsulation techniques are likely to be used

---

FDA approval procedures. (see 2.A.)

clotting factors
condition immune responses
brain, neurological effects
liver/kidney function

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: T. M. Prociv

AIDED BY: L. M. Curran

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

novel plastics
adhesives
materials for lightweight construction
coatings
pharmaceuticals (vaccines, phophylatics, therapeutics)

B. To what products or processes might it be applied?

aircraft and ship construction

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

lower costs
lightweight materials

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1.	affinity chrom--general industry--full scale	1989
2.	high pressure-lc--general industry--full scale	?
3.	electrophorenes--available NOW--	1985
4.	cell density sensor--Battelle patent	1985

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Australia--cell density sensor
Japan--novel efficient fermentor soon available
European countries (CHEMAP in Switzerland and BIOLAFIT in France) major suppliers of equipment

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- in situ (mutation) detector for contamination

- smaller fermenters for higher cell density

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

Key: 1,2,3,4 same as 2.A. (above)

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1. 1989 2. ? 3. 1985 4. 1985	Industry Industry Industry Battelle, pate
2. First Experimental Device application (or first experimental process demonstration)	?	?
3. When available for inclusion in product or process?	?	?

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: BIOPROCESS TECHNOLOGY FOR MATERIALS [New]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Limiting factors are:

	Improvement
1. Separation Technologies (large scale)	
- affinity chromatograph (mono-clonal)	+200%
- high perf-liquid chromatography	+400%
- electrophoresis	+200%
2. sensors & control technology	
- measure cell mass, viability	+200% increase
- in situ product measurement	
- maximize production	

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1) - new packings for materials
- basic understanding of protein behavior under separation technologies

2) Smaller fermentors for higher cell mass

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: L. A. Kiesow

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Selective separation of individual materials. Military interest from material mixtures.
Removal of trace or undesirable components from materiel mixtures.
Large scale isolation and production of specific materials from mixtures.

B. To what products or processes might it be applied?

Separation of materials that are either antigens by themselves or can be rendered antigenic (so that antibodies can be obtained).

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Technology may serve in the production of materials and biologics which can be used to protect military personnel in adverse environments and to treat casualties.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Use emerged already. Methods for scale up and increase of antibody affinity and therefore efficiency; 2-5 years.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Technology is not restricted to US. Particularly industrial use is being developed at accelerated rates abroad.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This technology leads to new and more efficient separation techniques that open new technical approaches for industrial and consumer products such as: biologicals, pharmaceuticals, biomolecules.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975	US
2. First Experimental Device application (or first experimental process demonstration)	1980	Foreign/US
3. When available for inclusion in product or process?	1985	US/Foreign

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: BIOLOGICALLY-BASED MATERIAL SEPARATION TECHNIQUES [New]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Antibiotics (monoclonal or not) provide a high degree of specificity that can be direct against the proper antigen with which the antibody will combine. Depending of the avidity (affinity) of the antibody highly selective (10^5-10^{20}) separation of the antigenic material or antigen carrying materials becomes possible. Separations involve immobilization or typing of the antibody using physical or chemical means thereby allowi separation of the antigen-antibody complex. These techniques have been demonstrated to be successful in many laboratories in the US and abroad and have found applications in separation of materials which is otherwise difficult or impossible to acnieve.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Facilities to induce antibody production to a broad spectrum of antigens exist in many laboratories, industrial and otherwise. Capabilities to produce monoclonal antibodies existed for sometime and are being scaled up to manufacturing quantities.

US is using variety of physical and chemical separation approaches such as: immobilization, flourescent labelling, micro-magnetic marking.

8. What synergistic effects might this technology have on US military capabilities wnen combined with other technologies?

These techniques combined with C-B protection clothing and self-contained life support systems will increase the survivability and combat effectiveness of operational personnel.

REPORTER: G. T. Chisum

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The compounds will be used as pre-exposure agents to increase the LD 50 levels of the agents and as therapeutic agents to counteract the effectivenss of the C-B agents after exposure. They may be administered orally or by injection.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The technology will increase survivability of military and civilian populations and the combat effectiveness of operational personnel.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

20 to 25 years from the initiation of full effort to achieving a usable product

B. Estimate US status compared to any non-US work being done on the ET in question, or its inclusion in a (ours and theirs) defense system.

No known.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The perceived threat from potential enemies and the potential demonstrated for effect against the identified threat agents.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	mid 70's (Prosto-glandins)	US
2. First Experimental Device application (or first experimental process demonstration)	mid 70's	US
3. When available for inclusion in product or	some now	

TECHNOLOGY: PROPHYLACTIC/THERAPEUTIC COMPOUNDS FOR CBW AGENTS [A-14]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Applicable technology depends on the development of compounds to neutralize, deactivate and/or counteract the action of chemical and biological warfare agents. These compounds must be such that they can be administered in sufficient, non-toxic levels to achieve the required effect. The most probable periods of effectiveness of such compounds are 3 to a maximum of 24 hours and may be 50% effective. The technology may include monoclonal antibody, prostoglandins and chemical detoxicants.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Production processes required to produce monoclonal antibodies, prostoglandins and chemical agents are necessary to translate the technology into a production item. Twin release drug during delivery techniques may also be approaches.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Integrated CW defense systems cannot be developed without accurate identification of the agents. Identification, detection and quantification are key information needs when determing how to use other protective measures, i.e. protective garments, decontaminants shelters, medical treaments, etc.

REPORTER: T. M. Prociv

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- As a chemical contaminator "triage" for decontamination, non-contaminated individual or equipment need not be decontaminated if no agent is present.
- As a "fingerprint" method for identification of agents including (non-standard agents
- For identification of contaminants entering a life support system i.e., residual life implicators.

B. To what products or processes might it be applied?

1. combat systems, vehicles, shelters
2. space stations

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Substantial improvement in reconnaissance, particularly in the time saving associated with only decontaminating personnel, equipment and areas which may have experienced contamination.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1. Portable Tandem Mass Specrometers with API are not available--commercial instrument is available from SCIEX Corp.
2. Brucher Francen (Germany) has a single quadrapole MS (militarized)
3. Perkin Elmer Corp. has mini MS (tandem) in IR&D.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

1. SCIEX is a Canadian company.
2. Germany Recon system (FUCHS) has fielded a single quadrapole MS in a combat vehicle for reconnaissance.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- cost and size are drivers
- benefits can be seen in the environmental market

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

Key: 1,2,3 same as 2.A. (above)

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	1	1983	Battelle
	2	1983	German Gov't
	3	1984	Perkin Elmer
2. First Experimental Device application (or first experimental process demonstration)	1	1988	Industry
	2	1983	done/Germany
	3	1990	Industry
3. When available for inclusion in product or process?	1	1995	CRDC/Industry
	2	1988	CRDC
	3	1995	Perkin-Elmer

MISSION SUPPORT: BIOMEDICAL TECHNOLOGY

TECHNOLOGY: RAPID IDENTIFICATION OF CHEMICAL AGENTS [A-10]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Miniature Mass Spectrometers for the precise detection and identification of chemical warfare materials. Estimates range from 90-150% improvement in air-base operations. Over 100% efficiency improvement in ground and air reconnaissance with tandem mass spectrometers.
Can do biomaterials such as viruses using Curie flash sources.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- small, durable quadrapoles
- Compact pump and cryo-cool hardware
- Improved Atmospheric Pressure Inlet

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Overall improved combat effectiveness with higher survivability rates.

REPORTER: Elaine M. Andrysick

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Used to decon equipment, crew, support personnel exposed to CBW agents to increase survivability, reduce agent-induced injuries (blisters, etc.); increase battlefield effectiveness by reducing down time for decon and increasing crew/support personnel confidence and personal effectiveness. Barrier cream to provide protection between attack and equipment dowsing.

B. To what products or processes might it be applied?

The emerging technology can be applied to aircraft, ground troops, artillery; it could, in civilian sectors, be applied, perhaps, to hazardous chemical spills. It may be incorporated into a life support system (closed air cycle/regenerative air) in aircraft, tanks, portable life support system backpacks.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The emerging technology could effectively improve US military capabilities and survivability in a CBW environment by more than 15%. Allow effective operation in a contaminated environment without the problems of the current corrosive nature of the decontaminants.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1) CRDC--enzymatic decon system based on bio-processes
2) Battelle--OPAB, octyl pyridinium aldoxime bromide decon and barrier creame
3) USAF--microencapsulated decontaminants and indicators
4) USN--Phosphate based generation of peroxids

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

6.1 CRDC bioenzyme decon/US only
6.2 AF/Army programs on Freon showers/hot air systems
6.2 OPAB demonstrated/also investigated by Germany, Netherlands and Norway
6.2 Microcaps/also investigated in Germany
6.2 Peroxides--only in US

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

- military; resultant from extensive CW proliferation in Middle East and other third world countries, continued presence of Soviet stockpile;

- OPAB barrier cream can provide avg 6 hours protection on skin against VX, is non-tox non corrosive as a decon

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1. 1985 2. 1983 3. 1984 4. 1985	CRDC THAMA * Brooks AFB USN/IITRI
2. First Experimental Device application (or first experimental process demonstration)	1. 1988 2. 1985 3. 1987 4. 1990	CRDC/Industry MRDC ** ASD USN/NRL
3. When available for inclusion in product or	1. 1975 2. 1988 3. 1989	"

Battelle

TECHNOLOGY: DECONTAMINATION OF PERSONNEL AND EQUIPMENT EXPOSED TO CBW AGENTS [A-10]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The emerging technology can be used to cut refurbishment, cleaning and basic decon time by possibly 40% thereby increasing military effectiveness; the psychological factor of confidence felt by crew could result in 20% better battlefield effectiveness. Key ingredients are low toxicity and corrosivity and general capability to remove so-called "unknown agents."

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

-microencapsulation of decontamination enzymes/proteins
- quick identification of agent type
- all-temperature use
- material/uniform and skin, avionics compatibility
- non-toxic and non-corrosive
- recycleable
- method for detoxifying agent (upon physical removal)
- lightweight, mobile (for use on battlefields)
- quick acting

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Is an area unto itself.

REPORTER: Robert Newburgh

AIDED BY:

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1) Greatly enhance life of materials in marine environment
2) Diminish needs to put ships in dry-dock
3) Prevent degradation of paper, clothing, tents, etc.

B. To what products or processes might it be applied?

1) Materials used in ships, clothing, or other marine environments.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Decrease needs and time for replacement or repair of military equipment.

Decrease deterioration of oil rigs.

TECHNOLOGY: High Power, Frequency MM Wave.

High power compact mm wave antenna with distributed sources (D-4)

1 - DESCRIPTION

A. **Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.**

High power and high frequency MM wave transmitter and antenna systems are required to implement the next generation of EW jamming and radar surveillance systems. To generate power levels in ranges up to 1 megawatt effective radiated power (in light weight configurations) will require development of hybrid solid state and tube transmitters combined with integrated antenna techniques. High power mm wave TWT (or alternate) tube drivers are required to generate power levels $>$100 watts over several GHz of bandwidth. Solid state structures are required to offset attenuation losses in array antenna fed structures and permit achievement of power magnification through use of spatial combining techniques.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Current DoD sponsored and thrust programs in developing high power mm wave TWT's (Army ERADCOM ET&D and Air Force AFWAL)

2. Current DoD sponsored thrust programs for developing high power mm wave solid state amplifiers and sources-- GaAs FET design. Sponsors: Army ERADCOM ET&D, Air Force AFWAL, Navy (NRL?)

3. MM wave array antenna/integrated feed structure development efforts at ERADCOM EW Lab and HDL

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Demonstrator subsystem will be available by 1988/89. Will use current state of the art 20 watt mmw TWT; plus GaFet phase shifters, distributed amplified feed structures.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Soviets, UK leads US in tube development technology.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military need to counter mm wave radar and seeker threats.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

ILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Key Sub-sets in 1985	DoD tri-service Raytheon Lockheed Hughes
2. First Experimental Device Application (or first experimental process demonstration)	1988/9	Army EW Lab Air Force AFWA
3. When available for inclusion in product or process?	1992	DoD

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

CBA's would be sprayed on vehicles, such as ships, to reduce interference.

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Basic Rusty Bolt problem can be substantial. The successful development of effective CBA chemicals would be a major contributor to improved search and surveillance, as one example.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: C. Tesses, (202) 767-2121

AIDED BY:

TECHNOLOGY: Chemical Bonding Agents (CBA)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

"Rusty Bolt" effects concern the generation of interference to electronic systems due to intermodulation products from metal contact points, e.g., on ships. Chemicals have been developed at NRL, Chemistry Division, which can reduce these effects.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Appropriate chemical bonding agents have been developed for specific types of contacts, such as steel-to-aluminum, but not other types.

B. **Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.**

C. What needs/opportunities will drive this techn[illegible]gy (e.g. costs, military, industrial, consumer, environmental, etc.)? Be [illegible]s specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975	US (NRL)
2. First Experimental Device Application (or first experimental process demonstration)	1980	US (NRL)
3. When available for inclusion in product or process?	1995	US (NRL)

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The technology can be used to provide aircraft and cruise missiles a covert attack capability. It can provide fighter aircraft the capability to perform high confidence classification at very long range prior to committing weapons. It also can allow the selection of high value target (sorting of bombers from decoys, escorts, etc.) to get the most out of each target commited. The long range classification further can allow fighter aircraft to perform battle damage assessment to maximize effectiveness of on-board weapons.

B. To what products or processes might it be applied?

Airborne intercept radars, surveillance radars, cruise missile seekers and radar altimeters, and aircraft missile defense systems.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Enhance long range air-to-air capabilities of tactical aircraft and air defense of the Navy's fleets and USAF/USA air field, C^2 centers, etc. defense. Survivability of airborne forces.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: Douglas W. Cowan (NWC)
AV 437-2505/2984

AIDED BY: Bill Hickland (NADC)
AV 441-2141

Allen Tarbell (ERADCOM)
(201) 554-5171

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Low-Probability-of-Intercept (LPI) and Long Range Airframe Classification Radar for Airborne Intercept

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

LPI radar for application to reduced observable aircraft, and very long-range, high resolution radar technology for classification of threat aircraft airframes.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The primary component technology needed to implement the concepts are currently emerging in the areas of VHSIC, RF components, radar waveform and automatic classification of range-only-radar profiles.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

With adequate investment by DoD, the technology could be made available for introduction to production in the mid- to late-1990 time frame.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Unknown, but it is assumed that other countries are working very hard on aircraft reduced observability technology.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The design of the next generation of DoD air[illegible]aft will be driven by the requirements for reduced observability. In a[illegible]tion to reducing airframe and propulsion observability, there is a need [illegible] develop reduced observable radar technology to provide effective n[illegible]gation, search, targeting and attack capabilities. Also, need capabil[illegible]y to make friend, foe or neutral classifications to make attack decis[illegible]ns at very long standoff ranges.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. [illegible] your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1986	DoD
2. First Experimental Device Application (or first experimental process demonstration)	1992	DoD
3. When available for inclusion in product or process?	1995	DoD

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration Ubitron/ECRM	~ 1960	GE, Yale (Gorkii)
2. First Experimental Device Application Ubitron/ECRM	1964-1967	GE, Gorkii
3. When available for inclusion in product or process? Ubitron/ECRM	1984-1990	Service labs w/ industry

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

High power millimeter wave amplifiers are required for a variety of military applications. These include tracking radars for ballistic missile defense, fire control radars for ship defense against low flying cruise missiles, surveillance radars for low cross section targets, broadband amplifiers for ship-based electronic warfare, and satellite communication jammers. Fast-wave amplifiers are well matched to these projected and perceived system requirements and may represent the only technology which can meet these performance requirements.

Alternate applications in such areas as solid-state spectroscopy and chemical processing in the submillimeter and far IR can also be anticipated. Application in high energy accelerator is under study by the DOE.

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Without the development of practical fast-wave amplifiers the DoD will not have the high-power millimeter wave sources on which to base system developments required to meet critical military needs.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Related Technology Statements: D-4, F-19

REPORTER: Robert K. Parker (NRL)

AIDED BY:

TECHNOLOGY: Fast-Wave Amplifiers as Efficient High-Power Sources of Coherent Millimeter and Submillimeter-Wave Radiation

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Fast-wave amplifiers provide a unique opportunity to extend the performance of microwave power tubes to significantly higher powers in the millimeter and submillimeter-wave portion of the electromagnetic spectrum. At 100 GHz, fast-wave amplifiers are estimated to be capable of generating average powers in excess of 100 kW. This level of performance represents an increase of two to three orders of magnitude over more conventional types of power tasks.

Conventional power tubes require the use of a slow-wave circuit to reduce the phase velocity of the electromagnetic wave to that of the electron. This beam-wave synchronism is a requirement for energy exchange between the electron beam and the electromagnetic wave. For the slow-wave circuit to be effective, its transverse dimensions must be significantly less than the free space wavelength. This transverse dimensional constraint limits the electron beam power which can be propagated through the circuit and thereby the RF power of the tube.

Fast wave amplifiers take advantage of a transverse periodic motion imposed on the electron beam to couple a natural beam resonance (space-charge or cyclotron wave) to the electromagnetic wave. Since no low-wave circuit is required, the interaction circuit can be a simple cavity or angle of waveguide. The two major classes of fast-wave amplifiers are the free electron maser (ubitrons) and the electron cyclotron resonance maser (gyrotrons, gyro-TWT, gyro-klystron, gyro-BWO). The distinction is based on the character of the beam-wave interaction used for power generation. In the free electron maser, a periodic, transverse magnetic field is used to couple the pump shifted negative energy space charge wave to an appropriate waveguide mode. Alternatively an applied axial magnetic field is used in the electron cyclotron resonance maser to couple the fast cyclotron wave to TE waveguide mode near cutoff. Specific devices may use either a distributed or localized interaction circuit much like the conventional TWT or klystron.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc. which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Key issues in the practical development of the fast-wave amplifier include the following:

Ubitron
- development of advanced undulator designs based on permanent magnets and/or advanced magnetic material
- development of low emittance, high current density electron guns
- advanced circuit concepts for operation at low electron kinetic energy

Gyro-devices
- stable two-section tapered gyro-TWT designs for broadband performance
- high harmonic operation to reduce required axial magnetic field
- advanced magnetic materials for permanent magnet designs
- higher order mode gyro-klystron circuits
- high quality space-charge limited electron guns featuring low axial velocity speed

2 - STATUS

Describe the status of work at organizations whi:~ would be involved in developing this emerging technology:

A. Estimate time availability of the technology i.e. when will it be available for inclusion in a product or production process?).

- Active R&D organizations - NRL, Varian Associates, Hughes, University of Utah, MIT, UCLA, Dartmouth, Columbia

- Time availability of technology - related oscillator development is well-funded by the DOE and a variety of high power oscillators are available for plasma heating and isotope separation. Amplifier R&D which is primarily supported by the DOD has lagged. Practical devices appropriate for field deployment must feature low magnetic field and low voltage operation. Varian has provided several preliminary gyro-TWTs to the Army for radar studies in the Pacific. A basic capability could be available in 3-5 years. More complete exploitation of the potential may take 7-10 years.

- US/other status - The Soviets have consistently led the US in fast-wave oscillator R&D. Little reference has been given to the corresponding amplifier R&D in the Soviet Union.

- Needs/opportunity - Substantial enhancements of current capability are required to meet projected military needs for high power-millimeter-wave amplifiers.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Airborne octave aperture radars
- Shared aperture (combined radar, EW, COMM functions in common electronics)
- Space based radar and COMM
- Smart munitions
- Missile seekers
- Decoys
- Jammers

B. To what products or processes might it be applied?

See 3A.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

See items 2A and 3A for general impact. Additionally, it should be recognized that this only technology on horizon which, if successful, can allow for affordable active aperture systems. Also, this technology will greatly enhance (10's of hrs. currently to approximately 100's of hrs with this technology) the operational availability of RF systems due to improved maintenance costs and survivability to nuclear effects. This will also allow for maintained radar performance regardless of the weather or jamming environment.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   This technology is synergistic with E/O and digital signal processing technologies on common chips.

REPORTER: Doug Cowan, AV 437-2505

AIDED BY: Charles Bass, AV 933-6107

Barry Spielman, (202) 767-3312

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Monolithic GaAs and III-V Related Components

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Growth and/or deposition of multiple active and/or passive semiconductor devices and associated circuit elements on a single chip of semi-insulating semiconductor substrate. Primary emphasis for this technology is taken to be the microwave and mm-wave frequency regime.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Bulk growth of GaAs (or III-V compound) material (e.g. LEC, Horizontal Bridgeman)
- Epitaxy (VPE, MBE, MOCVD, VLE)
- Ion-implantation (incl. annealing techniques)
- Lithography (contact, projection photo, E-beam, X-ray, Ion-beam)
- Etching (Wet and Dry techniques)
- Other Processing Techniques (Polishing, Slicing, Dicing, Bonding)
- CAD/CAE (e.g., Compact, SPICE)
- Automated Circuit Test and Evaluation

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technology available for production of building block parts/standard chip sets in about 1990.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Japanese lead US in establishing advanced development/pilot production capability for microwave monolithic circuits. This is in response to perceived commercial market. French are possibly similarly advanced.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military requirements will be major pull for this technology, e.g., Wideband Transceiver (T/R) modules for radar, ESM jammers, and COMM., decoys.

These systems can utilize multi-function, multi-beam; cost-effective, reliable, radiation hard system implementations capability offered by this technology.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Circa 1980	Plessey
2. First Experimental Device Application (or first experimental process demonstration)	Early 1980s	Several domestic sources
3. When available for inclusion in product or process? Limited function	1983-1985	Numerous sources
Generic Chip Sets	1990	TBD

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Applications involve the optimum inclusion of built-in redundancy and self-healing reconfigurable features for improved reliability and maintainability.

B. To what products or processes might it be applied?

It might be useful for space based infrared astronomy, and spectroscopy and/or radiometry of materials at below 20K.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

A major improvement in the reliability of electronic systems is possible.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: C. Tesses, (202) 767-2121

AIDED BY:

TECHNOLOGY: Improved Reliability of Electronic Systems (L9/G18)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Reliability of electronic systems has been a major deficiency. Concepts for improved reliability of radar systems have been under development in the Radar Division at NRL which include built-in redundancy and self-healing signal processors.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

The experimental radar at NRL includes simultaneous operation in two frequency bands for increased reliability through redundancy. Also a solid state transmitter by the SPS-40 radar was built, featuring multiple plug-in modules for improved reliability and maintainability, allowing the radar to continue operating while modules are replaced.

Additionally, theoretical work has been done at NRL on concepts dealing with self-healing processors which reconfigure themselves in the event of internal failures. Excess parallel paths are provided to give this redundancy.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and the s) defense system.

C. What needs/opportunities will drive this techology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1975	US, NRL
2. First Experimental Device Application (or first experimental process demonstration)	1978	US, NRL
3. When available for inclusion in product or process?	1988	US

REPORTER: J. J. O'Hare (202) 696-4502

AIDED BY: C.L. Temes (202) 767-2121

(5) The speed of A-D converters limits the capabilities of embedded display systems.
(6) The limited memory capability in small package sizes represents design impediment.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration (a) Task-allocation technology (b) Embedded display systems	 1983 1983	 MIT, U. Illinois VPI & SU, Ga. Tech. NRL
2. First Experimental Device Application (or first experimental process demonstration) (a) Task-allocation technology (b) Embedded display systems	 1984 1984	 MIT and NOSC-San Diego and Woods Hole Jason Project NRL-prototype
3. When available for inclusion in product or process? (a) Task allocation technology (b) Embedded display systems	1986 1988	US Aerospace US

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The primary use of this technology is at the output of S&S and EW systems by a more effective means for the organization, representation, interpretation of the sensed events.

(1) The monitoring, detection, localization, designation, classification and decision/actions required for radar systems, sonar systems (both active and passive) and surveillance systems. These systems could be land-based, ship-based, sub-surface (platform or ocean bottom) or airborne (aircraft, satellite).

(2) The diagnosis or fault-detection subsystems of these sensor systems for monitoring the integrity of the system, detecting faults, isolating the source of failures, analyzing causes, and reaching decision/action with respect to repair/replacement.

B. To what products or processes might it be applied?

(a) Processes that are well understood would be the easiest

(b) Products (sensed outputs) that are incompletely presented as displayed within a noisy environment.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

This man-machine technology will provide these necessary goals:

- Improve real-time response
- Reduce demand for high manning levels for the use of sensor equipments
- Enhance the quality of decision making by focusing user effort on non-routine aspects of the task
- Permit the sensor system to operate at high levels of success with less frequency of uncertain events
- Permit the sensor system to cope more effectively with high rates of data input.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

(a) This technology when combined with improvements in remote sensing, data transmission, and object manipulation, would enlarge the time-window for the user's decision making. For example, compressed bandwidths and shaped optics for transmitting video data at greater distances, allows more time for analysis before an action is initiated.

(b) Higher data-storage capacity in processes for display systems will increase the quality of the informational analysis.

(c) Higher-speed of data processing will increase the probability of reaching a real-time response to the sensed events.

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Optimum Allocation of Decisions and Actions Between Human and Machines in a Man-Machine System (L4) (also related to L.20 & A.20)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Task-allocation technology for dynamic operational conditions has been demonstrated in academic laboratories and a theoretical approach has been developed that is effective in understanding of how operators monitor process-events. Software algorithms have been developed that: (a) Track operator performance in control actions for a task, acquire the operator's production rules, and are capable of assuming control of task. The operator's work is reduced from the more difficult level of continuous decision-making to the less academic level of discriminating significant change in the task conditions, detecting a task condition that the system finds to be new or unexpected, and monitoring or supervising the operation of a machine system. (b) Utilizing decision rules developed for the implementation or analysis of all events that contribute to the solution of some task, accept changes in those rules as expressed by the operator, and take into account the biases exhibited by that operator with corrective actions. (c) Utilize electronic and magnetic measures from scalp of operators to assess level of alertness, uncertainty about data interpretation, and attention to the specific task. These data can be used by the machine system to aid the operator in task performance. For example, response times for magnetic activity are of the order of 300 ms, as opposed to older computer averaging techniques that required about 30 sec. (d) Embed processors into display subsystems to perform pattern recognition, predict movement and identify new or unexpected events. For example in the new technology of micro-computer aided tracking (MCAT) at NRL, 32 targets can be tracked as opposed to approx. 6 with older technologies.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

(a) It takes about 2 years for each task to exhibit the production rules employed by the user and to express those rules in the system's model of the task situation. It would be anticipated that it would take approximately 5 years to categorize those data into generic rules so that there were general algorithms re software modules for the tasks of detection, localization, classification, designation, and decision-making.

(b) The development of user-acceptable, operational techniques for the transfer of system control from operator to the machine, and vice versa, would require an extensive training program for the users and their supervisors. Would estimate 2 years for the design and implementation of those training programs.

(c) The development of portable, cryogenic materials for the practical use of electro-magnetic techniques would take about 10 years.

(d) There are no critical components necessary for embedded displays that are not potentially available to develop large-scale production.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

(a) For the task-allocation technology, suc~ systems should be available by 1990
(b) For embedded display processors, this te~nology will be available by 1987

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

(a) Most non-US work is focused on fully automatic systems (cybernetic-theory based) rather than man-machine allocation techniques
(b) Antecedent technologies for display processors have been readily adopted by non-US governmental/commercial organizations, but comparable US organizations have continued to use old techniques.

C. **What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

(1) The inability of fully automatic systems to meet operational requirements; they are unable to support dynamic, current needs.
(2) The need for systems that can handle new or surprise events requires the incorporation of a human operator.
(3) The need to rely on a doctrinal response to sensed events can be reduced when a real-time system is operational.
(4) The prospective operational environment for space weapons taxes the technical flexibility of current systems.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

As a replacement/extension of cooled IR sensors the IR arrays have advantages of no cryogenic cooling or scanning components and increased dwell time. For higher performance systems, the improved sensitivity and image processing potential offer more area coverage with improved S/N.

B. To what products or processes might it be applied?

The low cost moderate performance arrays can be used as individual weapon sights, driver's aids, armored weapons viewing systems, and missile seekers (VIS and IR). Space systems can utilize the improved sensitivity and ability to assemble large arrays for space to space or space to ground applications. The airborne imaging systems can also utilize the improved sensitivity of cooled, high sensitivity. Large arrays for surveillance and targeting and smaller arrays for seekers.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The uncooled staring IR sensor has the potential to significantly enhance the Army's capacity to fight. If costs and power consumption (battery costs) can be made low enough every weapon and vehicle can have the capacity to operate in low/no visibility conditions with only slightly diminished capacity.

If these sensors can be used in missile seekers the sensitivity/array size allows range and intelligence improvements necessary for smart weapons with assembly of large arrays and sensitivity allows improved surveillance and targeting.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The array allows improved processing techniques to be applied. Change detection and moving target detection as well as improved processing techniques lend themselves to array outputs from imaging sensors. The extra noise and scan nonlinearity associated with scanning systems allows a higher quality image to be formed and processed. The array output also lends itself to optical processing.

REPORTER: James E. Miller, AV 354-1432

AIDED BY: Henry Lapp, AV 78-56141

TECHNOLOGY: High Density, Two-Dimensional Search & Surveillance Arrays for Visual & IR Imaging [G-24]

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

In the IR, a group of competing technologies has advanced beyond the "proof of principles" stage. Three distinctly different uncooled array approaches exist. These approaches are ferroelectric, bolometric, and a classified sensing mechanism. Specific performance parameters are classified.

In the VIS, the CCD array camera already exists. Scaling the array dimensions beyond TV compatible configurations is needed for specific military applications.

Cooled IR arrays with good sensitivity and uniformity are being developed in small array sizes. Larger arrays with improved sensitivity and uniformity are under development.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

In general, standard silicon processing should be adequate. One area which will stress existing technology is the area of fine line (≈ 1 micron) lithography for the IR sensors but this is of sufficient interest to the semiconductor industry it should be developed as a matter of process evolution.

The area of low noise, fast preamplifier arrays may limit translation into production. Breadboard IR sensors are often preamp noise limited.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

(IR) early 1990's in short range, medium performance systems (specific numbers classified). Mid 1990's in long range, near theoretical limit sensitivity systems (VIS) technology available now. MIL SPEC systems in few years to early 1990's depending on array size.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

No knowledge.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The military is by far the largest user of IR arrays. The needs are both for direct view and missile seeker applications. If power consumption can be controlled this market should be large enough to reduce unit costs substantially below existing cooled sensors.

The VIS array is probably driven by the comm cial (TV) market and higher pixel number/density arrays will be only a m tary requirement.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration IR 3-5 8-12 VIS	 early 80s early 80s mid '70	 RCA T.I., Hughes Fairchild, RCA, Others
2. First Experimental Device Application (or first experimental process demonstration)	1. & 2. in these	Are the same technologies
3. When available for inclusion in product or process? IR 3-5 8-12 VIS	 late 80s late 90's Now	 RCA, others T.I., Honeywell, Hughes, Rockwell Many

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Analysis of fusion/event sensor data depicted on map and event templates.

AI processing would
(a) Detect key events/information
(b) Track environment
(c) Predict by extrapolation upcoming events
(d) Classification of targets
(e) Generate appropriate event cases
(f) Multi sensor correlation to tracks

B. To what products or processes might it be applied?

EW Radar Surveillance, Combat Direction, IFF and NCIR, EW/WS, C^3CM and IR/EO surveillance.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

(a) Speeds up decision making
(b) Reduces need for number of support operators (forces structure)
(c) Improves Operator efficiency
(d) Permits automatic sensor data base and weapons system management.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

   Development of VLSI, VHSIC processors and symbolic languages is needed to implement AI algorithms in an efficient/affordable system suitable for deployment in tactical and strategic systems.

REPORTER: ____________________

AIDED BY: Nick R. Klore, AV 99532101

Gerald M. Peake, AV 933-2924

Douglas W. Cowan (NWC)
AV 437-2505/2884

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Automated Image Recognition and Classification Thru Uses of AI Techniques (L-I/L-I7)
Threshold Logic for Decision Making in Situations of Incomplete Information (L-I7)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Computer matching of new data with older data to correlate to classifications, events, tracks.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Algorithms, VHIC, high speed computation

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Initial template analysis capability will be demonstrable by 1988. Multi-sensor correlation capability available by 1987. Adaptive automatic target classification available by 1988.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US and UK are at comparable technical levels.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

1. Cost of manning military collection and surveillance systems will drive this technology.
2. Complexity of systems operation.
3. Large volume and diversity of sensor data to be analyzed in pseudo real-time.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration (limited)	prior to 1985	DoD
2. First Experimental Device Application (or first experimental process demonstration)	1987/ 1988	DoD
3. When available for inclusion in product or process?	1990s	DoD

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

BIB detectors will be used in sensors in space to detect, recognize and acquire satellites and missiles in space.

B. To what products or processes might it be applied?

It might be useful for space based infrared astronomy, and spectroscopy and/or radiometry of materials at below 20K.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

If the impurities in the epitaxial layers can be controlled sufficiently well (below 10^{12} cm^3 for background impurities of a particular type), this technology will allow the construction of sensors that are "ideal" for a particular application in the sense that their capabilities will be limited by fundamental physical laws rather than technology.

3. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

BIB detector technology is compatible with planar silicon signal processing technology.

BIB detector technology should be able to support sensor "self-calibration" at the one percent level to meet stringent accuracy requirements for target identification as a replacement for blackbody/attenuator calibrations in chambers.

REPORTER: John Geist, NBS

AIDED BY:

TECHNOLOGY: Blocked Impurity Band Detectors for the Low Background Long Wave Infrared (G22 revised)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Blocked Impurity Band (BIB) detectors are based upon photogeneration of free carriers from donor levels in an impurity band in a silicon host, coupled with hopping mode conduction in the impurity band. The addition of an intrinsic blocking layer over the impurity band makes the detector operate like a reverse biased photodiode rather than a photoconductor. The current state of the art has demonstrated 1) internal quantum efficiencies increasing from less than 10% at 5 μm to greater than 60% at 24 um, 2) improvements in radiation hardness, pixel-to-pixel uniformity and temporal response in a low background environment relative to other existing technologies. A saturable internal gain of unity has been demonstrated and more recently, a saturable internal gain of greater than 10^4 has been demonstrated.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The key to this technology is the growth of silicon epitaxial layers with tight control over the nature and concentration of the impurities in the epi layer. The level of control over the impurities obtained in the processing will determine the ultimate performance of these devices. Devices with spectral responses peaked at a specified wavelength in the 3 μm to 27 μm spectral region, as well as devices with 100% internal quantum efficiency over wide spectral regions are possible.

Except for the requirement of stringent control over the impurities in the blocking and impurity band epitaxial layers, the fabrication of BIB detectors is compatible with conventional planar silicon technology.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Less than ideal devices should be available by 1987; highly optimized devices should be available in the early 1990s.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US DoD aerospace contractors are the world leaders and probably the only current sources of BIB detector technology. However, Russian physicists have shown a great interest in hopping mode conduction in the past, and this technology is likely to find a receptive audience in the USSR.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The only need that will drive this technology in the near future is the DoD requirement to detect dim and bright targets against a low infrared background.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
BIB device	1980	Rockwell
unit gain	198?	Hughes
10^4 gain	1985	Hughes
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		
current devices	1987	Aerospace Contractors
optimized devices	1992	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Surveillance **
Communications **
Power transmission
Navigation and guidance (sensors)
Instrumentation

B. To what products or processes might it be applied?

Same as above
Also laser surgery appears a likely beneficial spinoff.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Highly significant **

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTERS: Hurdle, B.G.

Fletcher, P.C.

Etter, W.P.

TECHNOLOGY: Ultra Low Loss Fiber Optics (Together with Comments Pertinent to (J-3) Measurements of Physical Parameters) [J-1]

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Beryllium Flouride (BeF) has demonstrated potential of .01 dB/km. This compares with silica fiber which has a demonstrated potential of .16 dB/km and a theoretical potential of .14 dB/km. Cable in commercial communications usage is at .18 to .20 dB/km performance level. BeF can be used with existing transmission system components. Corning has demonstrated drawing lengths of BeF > 1 km. Other fiber materials having theoretical loss as low as .001 dB/km are being actively investigated (NRL, Japan, Britain); such as Zirconium F and Zanthium F (ZnF, XnF). Detailed performance **.

Combined with the development of low loss fibers is the use of physical sensors based on fiber optics resulting in improved sensors in areas of acoustic, pressure, temperature and rotational measurement.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Requires improvement in purification of component material, the development of techniques for fabrication of large quantities of fiber optic at low cost together with search for lower cost (more readily available) material.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

BeF - 1990
Adv. Mat. - 1995 to 2000

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

On equal technology level with Japan with England and France close (behind)

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military primarily with industrial use most probable for transocean communications. If loss in IR region 5-10μ can be made sufficiently low then commercial power transmission will likely contribute to development.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration BeF Adv. Mater.	 1985 1990	 NRL/ Japan
2. First Experimental Device Application (or first experimental process demonstration) BeF Adv. Mater.	 1988 1994	
3. When available for inclusion in product or process? BeF Adv. Mater.	 1990 1998	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Low-noise receiver front ends for microwave and mm-wave frequency regimes.

Transmitter devices for microwave and mm-wave application. These will find use in radar, communication, seeker, and electronic warfare systems operating at microwave and mm-wave frequencies.

B. To what products or processes might it be app``ied?

Low-noise and power amplifiers. Control comp ~ents (e.g., switches, phase shifters). Frequency conversion (e.g., mixer` .

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Higher frequency system capability with associated cost, performance, and reliability improvements over currently available technology. Example is capability provided for mm-wave active aperture (i.e., multi-beam agile) systems.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Successful development of this technology can provide basis for marriage of microwave/mm-wave RF functions with electro-optic devices and digital signal processing technology on common chips or single "components."

REPORTER: Barry Spielman , NRL, Code 6850

AIDED BY: Charles Bass

TECHNOLOGY: Heterostructure and Superlattices of layered materials (G14)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Opportunity stems from capability for thin, sharply defined layers of semiconductor.

Heterostructures--generically as alternating layers of materials (e.g. GaAs, $Al_xGa_{x-1}As$) or alternating doping concentrations in similar materials.

Superlattices--periodic repetitions of heterostructures.

Devices--High Electron Mobility Transistor (HEMT) (also MODFET)
--Heterojunction Bipolar Transistor (HBT)
--Quantum State Transfer (QST)
--Coherent Injection for Reflection and Penetration (CHIRP)
--Negative Resistance FET (NERFET)
--Charge Injection Transistor (CHINT)
--Also detection and mixing diodes

Potential Benefits

- Higher frequency gain than traditional devices (i.e. GaAs MESPETS)
  - with associated low-noise (now) for small signal devices or
  - potential for efficient generation of power (1/2 micron gate length HEMT has yielded performance approaching 1/4 micron MESFET technology.)

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Epitaxy using Molecular Beam Epitaxy (MBE) now primary method. Potential Metal-Organic Chemical Vapor Deposition (MOCVD) and Vapor Levitation Epitaxy (VLE).

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Microwave components and discrete devices should be available within 1988-1990 timeframe, millimeter-wave devices and microwave monolithic components should be available in about 10 years.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

- Japan is also working this technology with about comparable to slightly lagging capability relative to U.S.
- French (Thompson-CSF) reportedly have demonstrated HEMT low-noise devices with the better performance than that reported to date by U.S. sources.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military drive (almost exclusively) for analog technology with opportunities for environmental-related payoff in radiation hardness benefits for space-related applications.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985	TRW Thompson, CSF Cornell Univ.
2. First Experimental Device Application (or first experimental process demonstration)	1985	Universities
3. When available for inclusion in product or process?	1988-1990	Several Sources

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Focal plane arrays have a variety of applications

- Search and surveillance (IRST, space based-IR)
- FLIRs for navigation and targeting
- Imaging sensors for missile guidance, terminal homing and fuzing
- RPV expendible sensors

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Radically lower the complexity of FPA signal processing by reducing the data stream up front on the detector. Signal processing for FPAs is driven by pixel size (array density), frame rate, and dynamic range. Signal processing requirements escalate rapidly if any of these factors (density, rate, range) is increased substantially.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

- Makes possible lock on after launch autonomous missiles with near zero CEP accuracy

- Cheap, portable, high resolution, search and surveillance

REPORTER: Pat McDermott

AIDED BY:

TECHNOLOGY: Integrated Optical Sensors/Analog/Digital Processing Elements in a Single Chip Focal Plane Array (G-4)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

This technology development is aimed at reducing the signal processing load/number of leads exiting from a two dimensional array by colocating the signal processing or at least the preprocessing circuits on the same chip as the detector array. If circuits are not located on the chip itself, some benefit can be derived by butting and mating the preprocessor directly to the FPA.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Detector materials growth processing and device fabrication
- VLSI/VHSIC level manufacturing capability
- High quality analysis equipment, e.g. scanning electron microscopes
- Signal processing algorithms, architecture
- AI for image segmentation, shape definition and templating near the source (FPA detector).

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

NVEOL

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US ahead in most technologies associated with the ET.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Performance is the main driver together with cost. Real time, high frame rate, imaging if primarily a military requirement. Visible FPAs for commercial applications (TV cameras may benefit from on-the-chip processing but may not be a principal driver).

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	?	
2. First Experimental Device Application (or first experimental process demonstration)	?	
3. When available for inclusion in product or process?	1990s	

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Process FFT (Fast Fourier Transform) in a few milliseconds or less instead of 10's of milliseconds as presently achieved with array processors. Process calculations in simulations in less space and weight so that "what if" projections can be made onboard tactical vehicles. Most simulations in EW require 1 second time frames (updates). This means many calculations for a battle scenario each second. Optical processing (parallel) offers possibility of detector array gain and offset correction and real time "template matching".

B. To what products or processes might it be applied?

Replace heavier and slower array processors in processing digitized FFT streams for EW and pattern recognition. High dynamic range analog optical processing could replace A/D → Fast Fourier Transform digital processing for these applications and be much faster and lighter.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Closer to real time ECM
- Better EW capability against spread spectrum signals.
- Onboard "what if" simulations in EW.
- The degree of impact is classified but is significant.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

This technology coupled with higher dynamic range (more bits) and faster A-D's (millions of samples per second) will significantly enhance the tactical EW capability against spread spectrum signals.

REPORTER: Gerald M. Peake
NOSC (619) 225-2924

AIDED BY: James E. Miller
NVEOL AV 354-1432

TECHNOLOGY: Melding of best features of digital and analog computing, including optical processing, to get extremely high computation rates, with appropriate dynamic range, on many parallel channels (E-14)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- Application of VHSIC to rapid-lightweight digital processing
- High dynamic range acousto-optical processing to separate RF components. Could use in place of A→D for FFT and digital processing of the FFT's. Requires development of high dynamic range A-O devices.
- Two dimensional spatial light modulators for optical processing are emerging but dynamic range is marginal.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

VHSIC

Acousto-optics

Non-linear optic materials for optical processing are produced at few institutions/companies. These materials are still in the research area in general.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Lightweight-fast processing of digital data is probably tied to VHSIC. Guess with funding of about $1 M per year for four years could have a working model. Optical parallel processing is farther in future. Low level uniformity correction may be in early 1990's.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need is here. Only money drives the VHSIC digital processing. Optical parallel processing as a front end "pre-processor" offers the opportunity to reduce the information / speed requirements of this digital/VHSIC processor. Optical processing at front end (preprocessor) must have dynamic range in order of 70 dB and above.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR A-O	YEAR VHSIC
1. Proof of scientific principle demonstration	?	1987
2. First Experimental Device Application (or first experimental process demonstration)	?	1989
3. When available for inclusion in product or process?	?	1991

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Prior to 1985	DoD Industry
2. First Experimental Device Application (or first experimental process demonstration)	1988	DoD Army ERADCOM
3. When available for inclusion in product or process?	1992	DoD Industry

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Design of all military ADP and signal processing systems

B. To what products or processes might it be applied?

All of the above

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Significant in terms of permitting efficient P^3I of tactical computer based systems. Will permit configuration of multiple signal processors around a common set of processing modules. Will permit efficient modification and maintenance of existing software/hardware.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

   1. Will provide at least a 20% reduction in the cost of developing, modifying and maintaining ADP systems.

   2. Will be a DoD/industry wide design tool and standard applicable for future ADP and signal processing systems development.

REPORTER: Dirk R. Klose

AIDED BY: B.G. Hurole

TECHNOLOGY: Framework for Modular Signal Processors (E-13) - High speed computers . . . parallel and array processors in compact portable modules. (E-7) - Computer language which is really appropriate for parallel processing. (D-3) - Automatic mapping of signal processing algorithms described in high level language onto specific multiprocessor architecture of VLSI configurations

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The complexity of VLSI and VHSIC signal processing chips/modules; the multiplicity of signal processor and computer architectures; and the general lack of support software and operating systems for general purpose array processing systems have severely limited the transition of high speed, modular array processors into tactical ESM, radar and image processing systems. In order to: (a) develop optimum parallel/array processor configurations;(b) implement VLSI/VHSIC processing module configurations; (c) efficiently develop processor operating/support software; and (d) translate existing algorithms into efficient representations on new signal processor architectures will require development of a new generation of CAD and system simulation tools needed to design state-of-the-art VLSI/VHSIC modular processors. The ERADCOM "Framework for Modular Signal Processors" program has taken on the challenge of developing these CAD/simulation tools.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

(a) A number of VLSI and VHSIC CAD and ship simulation software packages exist. Present programs include STARS, EMSP, SPL-1, ADA, etc.

(b) Likewise a number of high level computer architecture simulation packages also exist which permit evaluation of processor configurations.

(c) Several thrust programs exist for development of languages suited for parallel processor implementation.

(d) What is missing is a complete, integrated software package which is capable of total hardware and software simulation of complex parallel/array processor configurations.

(e) Additionally, improved designer/operator interactive/user friendly interfaces must be developed.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Initial pilot capability will be available within three years. Key working elements of the projected capability already exist.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Comparable technical thrusts and capability exist within the UK and Japan.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Drivers - cost of developing new processors with VLSI/VHSIC devices
- military need for efficient P^3I of existing hardware
- cost of transporting existing tested software from one machine architecture to another

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Signal processing for specific S&S/EW equipment
2. Battle management and control
3. S&S by intelligence analysis
4. CADE for military systems
5. Generation of new doctrine for battle engagement

B. To what products or processes might it be applied?

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. Would allow for quicker analysis of battlefield information, both for C^3 and S&S/EW
2. Improve interpretation of system inputs
3. Improved system design from CADE

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

1. When combined with useful sensors: very fast interpretation of battlefield situation
2. With algorithm development: fast, flexible signal processors
3. With improved circuit design algorithms: superior CADE

REPORTER: H. Bruce Wallace

AIDED BY:

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: High Speed Computers--parallel and array processors in compact portable modules (E13)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

1. >200 mflop speed
2. >4 ft^3 volume less power supply
3. <5 kw power required

Associated technologies:

1. Natural languages
2. Ichons
3. Networking

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. GaAs manufacturing
2. Compact cooling
3. Power generation
4. VHSIC
5. Ceramic packaging

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1995--Status: Architecture is still being developed as component production capability advances.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US is vastly superior to others in the hardware. The software and operating systems are being studied in Japan, England and France.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This technology sees immediate usefulness in dedicated signal processors; however, its use as a decision making tool has greater implications. These decision making processes are still trying to emerge.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1986	US
2. First Experimental Device Application (or first experimental process demonstration)	1988	US
3. When available for inclusion in product or process?	1995	US

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Can be applied to both pro and anti submarine warfare.

B. To what products or processes might it be applied?

Potential value to industrial noise reduction.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Significantly**

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Change of military tactics.

REPORTER: Hurdle, B.G.

AIDED BY: Etter, W.P.

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Active control of radiated sound together with Active control of reflected sound (018, 019)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Technology development for reducing the signatures of both radiating and reflecting or scattering acoustic targets by at least 10 dB. This also requires the determination of the elastic properties of acoustic targets.

B. List and describe related manufacturing know-now, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

This may require the development of techniques to apply plastic transducer material to target configuration and the related manufacturing techniques for fabrication.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Data not available**

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Prior to this time	**
2. First Experimental Device Application (or first experimental process demonstration)		"
3. When available for inclusion in product or process?		"

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. *How might it be used?*

Applications relate to improved radar detectability of difficult targets, including low radar cross section targets and seaskimmers.

B. *To what products or processes might it be applied?*

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Substantial impact in terms of improved detectability may result.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: C. Temes, (202) 767-2121

AIDED BY:

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: High-Power Narrow-Width Pulse (020)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Radar pulses have been limited in peak power by the specific types of tubes used. New approaches to tube lengths using multimode message structures allow much higher peak powers and combinations of such tubes can produce even higher peak powers and very narrow pulses which may have special advantages for detectability of difficult targets

NRL has been developing technology at both high mm wave gyrotron frequencies and low (VHF) frequencies which will allow the development of powerful devices within a decade.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Gyrotron fast wave transmitting tubes with 1 megawatt of peak power and 10 NSEC pulses at 94 GHz can be available within a year or two, based on work in the Plasma Physics Division at NRL. Soviet gyrotrons have already exceeded this pulse energy.

Also, low frequency slow-wave devices can be available in a few years, based on the work at NRL in the Electronic Devices Division.

Within a decade, one or two orders of magnitude increase in peak power and pulse widths on the order of 100 picaseconds may be feasible.

B. Estimate US status compared to any non-US w··k being done on the ET in question/or its inclusion in a (ours and thei··) defense system.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1970	US (NRL) Soviet Union
2. First Experimental Device Application (or first experimental process demonstration)	1980	US (NRL) Soviet Union
3. When available for inclusion in product or process?	1990	US

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The major impact of this technology area is on the ability to protect military platforms. Low signature, in general, would permit the manufacture of EW systems of relatively simple design using within reach technology (e.g. solid state in some cases and manufacturable TWT's for others). New approaches to decoys (active and passive), jammers, and tactics become available where signature is low.

REPORTER: Friedman

AIDED BY: Tarbell

Wallace

McDermott

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

UK has an active program for ships which leads ours. US has active programs for aircraft which probably leads the world. Soviets are likely to have a vigorous program.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military only. Major motivation is to improve survivability of attack by weapons guided by energy in the normal EM threat bands. Extraordinary success could produce vehicles which could escape detection except by the most sophisticated sensors.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	ALL	CLASSIFIED
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Develop integrated military platforms which could escape detection by the bulk of enemy sensors.
- Develop integrated military platforms which may not be acquirable by terminal threats or may be easily protected by simple EW resources.

B. To what products or processes might it be applied?

All military platforms likely to be the focus of enemy attack.

Survivability and intelligence have always been key to success on the battlefield. The two are frequently at odds. For example, to better observe what the enemy is doing may require intell platform flying higher for better visibility of distant forces or may require ground vehicles to penetrate enemy lines. Obviously, flying higher and penetrating enemy lines are not conducive to survivability. However, some or much of the risk of detection by enemy forces may be eliminated through reduction of useful signatures, particularly radar. Reduction of returns may be performed passively through careful design and selection of materials providing reduced radar, IR, and visual signatures or it may be performed actively through the radiation of signals designed to null radar passive reflections. Key technologies in absorbing materials, antenna design, airframe, or ground vehicle design and controllability, and waveform generation are emerging. These technologies must be aggressively pursued.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The technology is capable of enormously increasing the survivability of military platforms. As a consequence tactics, weapons delivery, and the ability to prosecute an attack will be much more effective. Lower own force attrition rates in ships and aircraft also has high impact on the entire military logistics and supply chain.

This technology of reducing detectable signatures of vehicles will allow intelligence gathering vehicles to fly higher or closer to the FLOT without sacrificing survivability thus overcoming line of site limitations and providing longer range intell.

SEARCH & SURVEILLANCE/EW

TECHNOLOGY: Technologies Associated with Reduced Signatures [Military Platforms] (D14, 15, 16)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

A new technology which has borrowed heavily from well known approaches to signature control of military platforms is emerging. This technology involves multi discipline research in signature prediction (computer or scale model modeling), shaping materials, and the conflicting demands imposed by simultaneous signature control in a number of search, surveillance, targeting, and terminal threat bands (UHF, microwave, mm wave, and IR). Furthermore, new techniques to control the signature of critical vehicle equipments, like tracking antennas, show great promise.

Reducing a platform's signature often extracts a penalty in terms of other performance parameters such as speed, range, engagement, envelopes, etc. The emergence of other technologies however can be used to compensate for and perhaps overcome some of the penalties so that the platform does not lose essential capability. For air platforms, for example, manned aircraft and missiles, the development of active control (control configured vehicle) and better understanding of thermodynamic cycles in propulsion including new materials for fabricating engines, allows a broad range of systems for the designer. The development of large computer models for designing air vehicles also is a major contributor to the capability of the designer to engineer low signature (RF, IR) while at the same time maintaining or optimizing more traditional military goals such as range, payload, speed, reliability and cost.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Materials

  a) wide bandwidth (!), high loss, low reflectivity
  b) low weight
  c) good environmental and chemical tolerance; fire retardant
  d) load bearing/structural materials for selected parts of aircraft and ships

e) methods to reduce edge currents
f) surface coatings which reduce IR emissivity while not increasing reflectivity at RF
g) techniques for achieving low signature at UHF

- Manufacturing Methods

a) control of large structures to maintain precision of manufacture
b) attachment procedures and long term maintenance of these materials
c) low cost, high speed fabrication methods
d) integration of avionics/combat hardware into platform without upset of low signature
e) wake control

- Prediction Tools

a) development of flexible, accurate, fast execution digital prediction models for signature
b) development of scale model facilities (larger scale factors ~ 200:1)

- Associated Equipment

a) low IR signature engines
b) exhaust signature control
c) RF emission control (LPI radar, comms)

- Colateral Technology Developments

a) active and passive aerodynamic control
b) composite materials for tailored shapes and enhanced direction stress
c) aero elastic tailoring
d) adaptive flutter suppression
e) unconventional thermodynamic cycles
f) coatings and materials development for lower weight engines

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Continuous availability of materials and technology with improved performance available over next 20 years.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration Single signature devices	RF-78 IR-?	Navy All sources
2. First Experimental Device Application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Devices will be used to increase the survivability of combat platforms.

2. Devices can be used with a prescribed separation (including free fall from A/C or rocketed from a ship) from victim platforms or can be towed by victim platform.

B. To what products or processes might it be applied?

1. Monolithic microwave integrated circuits

2. High energy, rapid activation, long shelf-life batteries

3. High power tube

4. Airborne launchers for all service use

5. RPV's for decoys

6. IR sources

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The multi-signature decoy will in some cases eliminate the need for on-board DECM for combat platforms. In other cases the on-board systems will have increased effectiveness when used in conjunction with off-board devices. Load-out and inventory may be simplified.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

1. Result in one device that will counter more than one threat.
2. Offer countermeasure to dual mode missile.
3. Devices can be used for cover and deception application.

REPORTER: W. Hicklin, NADC

AIDED BY: G. Griedman, NRL

R. Parker, NRL

TECHNOLOGY: Multi-signature decoys (including visual holograms) (D12)

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Tests and analysis have demonstrated that off-board (expendable) decoys will improve combat platform survivability when these devices are deployed against certain threat systems. One decoy device (POET) is in production to protect Navy combat aircraft. Also several devices are under development for devices to protect combat ships. These devices are primarily single signature devices. If threats become dual mode, then the need for multi-signature devices will increase. The airborne deployed devices must be packaged to be deployed from existing or totally new launchers (approximately 40 cubic inches) and must fly in a predictable trajectory. The solid state RF units must cover multi-octaves in frequency and be capable of * watts cw. Tube based units will be decoys will be capable of multi-octaves in frequency and up to * watts cw. Ship decoys generally require more power or cross section but do not have to be concerned with doppler. TWT based decoys containing provisions for mm wave and IR sources are possible.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

(1) High energy density battery that exhibit millisecond turn-on time and at least 5-year shelf life.

(2) Monolithic microwave integrated circuit (mm IC)

(3) Capability of growing 3 to 4 component semiconductors

(4) Monolithic microwave and millimeter wave initiative (M^3I)

(5) Construction of closely spaced high isolation antennas

(6) Fabrication of flare materials or other IR decoy concepts capable of covering projected threat missile IR bands with * watts/SR for aircraft and * watts/SR for ships.

(7) New manufacturing techniques to reduce size, weight and cost of various high power tube devices.

(8) Decoy platforms which move in a way to prevent discrimination from the host vehicle.

(9) Spectrum controlled IR decoy fuel materials which defeat color discrimination seekers.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

With increased emphasis and funding multi-signature devices can be introduced to operating units by 1990.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

The only known decoy devices being used or developed by non-US industry is in chaff rounds or IR flares.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

(1) Cost of buoying, installing and maintaining on-board DECM (defensive electronic countermeasures) equipment.

(2) Inability of on-board DECM system to generate track angle errors in certain type missile systems.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

High speed A/D conversion would allow EW and radar system architectures currently in use at lower frequencies to be applied to the microwave region. Particular application examples include broadband EW receivers capable of monopulse DF and frequency measurement to a high degree of accuracy and resolution and operation in dense and multiple simultaneous signal environments.

Detection and measurement of spread spectrum signals for EW.

B. To what products or processes might it be applied?

The specific need and application of high speed A/D convertors is in the area of signal parameter measurement for both EW and radar signal processing applications.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The technology would provide surveillance capabilities that are currently not feasible. Most effective use of this technology will be found in conjunction with VHSIC based devices that can handle the increased data rates and processing requirements. This technology will permit the development of wide band digital receivers for EW and radar surveillance systems. This technology will allow use of digital processing technologies in EW and radar systems currently only feasible in sonar and HF systems.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

See A
See E14

REPORTER: S. Davezac

AIDED BY: Dirk R. Klose
Gerald M. Peake,
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SEARCH & SURVEILLANCE/EW

TECHNOLOGY: *High Performance A/D Conversion (D6)*

1 - DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Development of ultra fast, high resolution A/D converters is a significant thrust in the DoD community. Generic capabilities on the order of GHz sampling rates and 8-12 bits of resolution are needed to satisfy various EW, radar, and image processing requirements. The lack of fast A/D conversion has significantly limited the applications of advanced digital signal processing techniques to next generation EW/radar systems.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

GaAs FET device manufacturing evolution.

2 - STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Use of GaAs FET devices will permit demonstration of 8 bit/1 GHz A/D's by 1988.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

US currently in the lead with the Japanese no more than a year behind.

C. What needs/opportunities will drive this technology (e.g. costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Application to military systems and high data rate communications systems.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Before 1985	DoD Industry
2. First Experimental Device Application (or first experimental process demonstration)	1988	DoD Hughes TRW
3. When available for inclusion in product or process?	1992	DoD Industry

3 - APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Development of mm wave jamming and radar surveillance systems for Army, Navy and Air Force.

B. To what products or processes might it be applied?

1. MM wave TWT, gyrotron, and solid state source developments.
2. Advanced mm wave antenna system.

4 - IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Provides new capability where a significant capability limitation exists.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

This technology represents the integration of several emerging technologies into a complete capability. To achieve necessary goals will require pushing of mm wave tube, solid state device and antenna technologies.

REPORTER: Dirk R. Klose
AV 995-3201

AIDED BY:

TECHNOLOGY: HIGH SPEED, HIGH CAPACITY COMPUTERS [D-6, E-(1,5,6,7,8,11,12,13), G-(3,10,19)]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The emergence of very high speed, high capacity computers as described in the above documents will have tremendous effect on all elements of manufacturing. This is due to the extra-ordinary large amounts of data that are required for manufacturing, including complete digital representation of part geometry and processing requirements. The size of computer data bases for manufacturing can be several orders of magnitude larger than those required for more common applications such as computer aided design. Current times for manipulation of these data could be reduced 90-95% thereby leading to many "real-time" applicati Additionally, these new computers should allow easier communications among various data bases and support the expanding need for off-line programming.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Most of these are listed on the Delphi documents. No unique capabilities for manufacturing applications are envisioned, except to assure some of the computers are "production environment" hard.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Most elements are 1995 for manufacturing applications.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

This is well documented in the computer science literature; however, applications in manufacturing are probably farther ahead in Japan and possible W. Germany.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Speed of data processing to approach "real-time" control and ability to access extremely large data bases from distributed systems.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1985	Various Industry/ Univ.
2. First Experimental Device application (or first experimental process demonstration)	1990	Mfg. Tech Programs
3. When available for inclusion in product or process?	1995	Production

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The entire spectrum of manufacturing will require advanced computers. Clearly the key to improved manufacturing will be the intelligent use of computers. Computer integrated manufacturing of all military systems will be required for the highly sophisticated systems of the future.

B. To what products or processes might it be applied?

Unit processes, manufacturing systems & CAD/CAM, all manufacturing.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The current estimates are that advanced Computer Integrated Manufacturing (CIM) will result in a 50% improvement in manufacturing productivity, e.g. 50% cost reduction, 50% span time reduction, etc.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Combinations with CAD and integration with maintenance systems will greatly enhance the total life cycle cost of all weapon systems.

REPORTER: V. J. Russo

AIDED BY: All members

MANUFACTURING

TECHNOLOGY: ADVANCED SENSOR DEVELOPMENT [G-(2,4,21,24), J-(2,3,4,5,9), K-(1,3.]

1. DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Advanced sensors are required to permit automated manufacturing in an unstructured environment. Sensors needed include optical (IR, UV, visual), tactile, acoustic. Developments required are reliability and increased sensitivity.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Sensors
high speed computers
AI based algorithms

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Some of it available now. Development to technology demonstration by 1990.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US probably slightly ahead.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Increased automation in flexible manufacturing, particularly for low quantity production runs.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	before 1990	US Japan
2. First Experimental Device application (or first experimental process demonstration)	1990	US Japan Others
3. When available for inclusion in product or process?	1990-1995	US Japan Others

3- APPLICATIONS

Describe the potential manufacturing ~~military~~ applications of this ET:

A. How might it be used?

Intelligent automated flexible manufacturing

Improved sensor capability will also permit increased use of on-line inspection and real time process control.

B. To what products or processes might it be applied?

All shop floor operations.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

High impact in manufacturing. Improve quality through real-time control and reduce cost for small batch parts.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Autonomous vehicles, SDI, allow new highly controlled processes.

REPORTER: Reimann

AIDED BY: all members

MANUFACTURING

TECHNOLOGY: NEW/IMPROVED MILITARY CAPABILITIES BASED UPON "INTELLIGENT PROCESSING" CONCEPTS [C-14, E-17, G-(9,12,14), I-(7,8), J-10]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

New military capabilities (opportunity-driven) and unfulfilled military requirements (need-driven) are frequently critically dependent on improved manufacturing of complex, advanced materials (e.g., structural and propulsion materials for transatmospheric vehicles, carbon/carbon materials for cruise missile propulsion, electronic materials for VHSIC). The properties and performance of these classes of materials are very sensitive to complex processing methods utilizing multiple, inter-related steps, and are dramatically affected by starting materials, process path, and local conditions. Emerging technologies such as growth of extremely low defect GaAs and other single crystals, formation of superlattice structures for nonlinear optical materials, surface tailoring of properties, cure of advanced composites for air and ground vehicle structures can be best transitioned from R&D to production via an interdisciplinary approach combining improved process models, in-process sensors, and artificial intelligence.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. AI architectures designed to efficiently integrate improved process models, sensors which evaluate the state of the material in real time during processes.

2. Improved process models incorporating both thermodynamic and kinetic factors which are critical to active control of processes, and relate control variables (T, P, flow rates, etc.) to materials properties. Equipment needs here are for supercomputers which can handle realistic 3-D models of physical phenomena to simulate alternative process paths to assist in choice of best process path to achieve properties required.

3. Process model improvements will be invaluable in guiding future research efforts in new in-process sensor concepts, which are essential to AI control systems for processing.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

"Intelligent" processes will become available during the time-frame 1990-2000 based on current projections for support. This may be late as compared to activities in Japan in AI and expert systems if not pushed at a greater rate.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US status is at the forefront, but the gap is rapidly being closed.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

New military capability requirements such as indicated in item 3-Applications.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration No data	provided	
2. First Experimental Device application (or first experimental process demonstration)	1987-92	?
3. When available for inclusion in product or process?	1990-2000	?

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. GaAs and other single crystals--semiconductor devices, VHSIC, substrates for IR detectors.
2. Carbon/carbon composites incorporating oxidation protection--for cruise missile engines, rocket nozzles, etc.
3. Rapid solidification--new, permanently metastable aircraft, missile, and propulsion structural materials with increased durability, higher temperature capability, etc.

B. To what products or processes might it be applied?

1. Curing of composites
2. Processing of ceramic/ceramic and metal matrix composites

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Key to production of materials which are pacing elements in new systems concepts employing new generation of capabilities (TransAtmospheric Vehicles, advanced fighter aircraft, etc.)

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The use of in-process sensors driven by improved process models will reduce the requirement for costly NDE inspection, since the products will be continually inspected during manufacture. New concept in product assurance.

REPORTER: P. A. Parrish

AIDED BY:

MANUFACTURING

TECHNOLOGY: AUTONOMOUS MACHINE VISION/IMAGE RECOGNITION [L-(1,2)]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The development of vision sensors, recognition algorithms and computer software/architectures to permit robots and other associated machines to operate in an unstructured environment in the same way that human beings can. This requires real time vision processing approaching human capability. Need at least 2 orders of magnitude increase in speed of recognition.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

high speed parallel processors
refined recognition algorithms probably based on AI techniques
3-D high resolution sensors (cameras, lasers, etc.)

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Source level of capability already exists, but not capable of operating in real time. Development of high speed computers could permit technology demonstration in next 5-10 years.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

US believed to be ahead in computing capability and algorithm development. High level of interest in Japan and they are probably closing the gap.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Manufacturing--cost reduction through elimination of direct and indirect manpower

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration (not real time)	1985	US
2. First Experimental Devic application (or first experimental process demonstration)	1990	US Japan
3. When available for inclusion in product or process?	1995	US Japan

3- APPLICATIONS

Describe the potential manufacturing ~~military~~ applications of this ET:

A. How might it be used?

Application of robots in unstructured environment--increased flexibility more cost effective for low volume batch manufacturing.

B. To what products or processes might it be applied?

Virtually all shop floor unit processors

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Restore US competitive edge relative to free world countries. Provide better quality control/reproduceability in manufacturing processes.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Autonomous vehicles
Hazardous environments (bomb disposal)
Heavily dependent on AI developments.

REPORTER: W. Reimann

AIDED BY: all members

MANUFACTURING

TECHNOLOGY: MAN-MACHINE INTERACTIONS [L-(4,19,20)]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Typically the human experts in manufacturing spend at least 20% of their time interacting with machines, requesting status from computers, ordering equipment, etc. The emerging technologies described should cause at least a 50% reduction in these efforts.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Most of the know-how will be computer software and, therefore, its translation into large-scale production would not require major new equipment.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Some work is ongoing at various laboratories and Universities. A time frame of 1990-95 is appropriate.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

No hard data are available; however, it is not an area where US would have a large lead.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The need to reduce the "indirect" (or non-touch labor) costs of manufacturing is of paramount importance. Today, 70-80% of the cost of batch manufacturing is associated with non-touch labor. Need for people to more readily accept interactions with machines and computers in manufacturing.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	-85 -88	Limited Mfg. related
2. First Experimental Device application (or first experimental process demonstration)	-90	Industry or Res. Labs
3. When available for inclusion in product or process?	-95	Industry

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

There are an extremely large number of applications in manufacturing where man-machine interactions are required: from the machine operator on a factory floor to the process planner or scheduler who must interact with computer systems. Developments that lead to improvements in these interactions may lead to the ability to reduce the time spent on them or to allowing complex, highly skilled jobs to be performed by novices.

B. To what products or processes might it be applied?

Examples would include "expert machine operators," i.e. direct labor systems that would always perform as if the manufacturing expert were controlling the process, e.g. machinery. Other processes would include a wide variety of applications in the "non-touch" labor part of manufacturing such as: scheduling where the human limitations would be readily accounted for; factory layout where the psychological elements would be included in the design; and inspection techniques where the human's concentration limitations can be accounted for.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The benefits gained in the manufacturing environment would directly translate to increased US military capabilities through reducing cost, increasing flexibility etc.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

When combined with advances in computer science and sensor technology, it could make a difference in the total flexible manufacturing capability of the US (e.g. a 50% reduction in cost and schedule) and, therefore, provide more military capability at the same cost.

REPORTER: V. J. Russo

AIDED BY: all members

TECHNOLOGY: MANUFACTURING SYSTEMS INTEGRATION TO ENABLE FACTORY OF THE FUTURE TO BE A VIABLE CONCEPT [L-16]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The use of computers, sensors and robotics to allow the operation of factories without people on the factory floor. The factory computer control system uses "information" bases and raw materials to manufacture products. The integration needed starts with design for manufacture, ends with storage and includes all facets of planning, processing and quality assurance.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. accurate models of the materials processing steps involved.
2. real time in situ sensors for the processes.
3. computer architectures, communication networks and algorithms appropriate for control of real time processes in a distributed environment, and appropriate for planning manufacture of a final product.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

Work on computer integrated manufacture (CIM) is ongoing in several large US companies with respect to "hard line" manufacturing (single product, "large" volume). Estimate availability in 2-5 years. Translation to DoD "Batch" manufacturing is perhaps 10 years away.

B. **Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.**

Foreign competition in this area is very intense in Japan and in Western Europe. The US position is anywhere from 3 years behind to 3 years ahead depending on the area of manufacturing.

C. **What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

Costs and reliability will drive the general area of CIM. CIM for batch manufacturing will probably be driven by DoD needs in this area. CIM suggests the possibility of a flexible product line with respect to a class product (i.e. small metal machined parts), with greatly reduced planning (cost), and rapid turnaround.

D. **Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.**

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

To greatly reduce the cost and time required to produce small batches of manufactured parts. At the same time it could increase the flexibility of the manufacturing system with respect to product variation and rate of production. (surge capacity).

B. To what products or processes might it be applied?

To virtually any manufactured product. Small machined parts, small assemblies, trucks, jeeps, subsystems for aircraft, ships, tanks; munitions, or rocket motors.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

The flexible computer Integrated factory could allow the drastic reduction of spare parts inventories, the acquisition of less expensive or more capable equipment, the opportunity to build surge capacity into information bases, flexible manufacturing hardware and trained human resources.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The presumed flexibility allows the upgrading of a particular equipment without the enormous expense we now face. A variation in process or a small change in design could be easily and cheaply integrated if new capital equipment were not required. For systems where new equipment was required the integration into the process could be greatly assisted.

REPORTER: W. Schmidt

AIDED BY: all members

MANUFACTURING

TECHNOLOGY: PROCESSING OF LIMITED/NON-ERROR-FREE DATA SETS [D-2, L-17]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Ability, presumably through advanced AI techniques, to resolve incomplete or conflicting data from a series of sensor or other inputs.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

High speed computers
Software/architectures based on knowledge based systems.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

Demonstration of technology possibly by 1990. Availability to manufacturing industry in 1995-2000.

B. **Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.**

Not much work been done to date in manufacturing.
US perhaps slightly ahead.

C. **What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

Requirement for increased intelligence at shop floor level means more sensors and information that must be processed. Uncertainties in quantities and schedules can be more easily accounted for.

D. **Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.**

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	-1990	US Japan
2. First Experimental Device application (or first experimental process demonstration)	-1995	US Japan
3. When available for inclusion in product or process? (MFG)	2000	US Japan

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Would be used in all elements of manufacturing in both direct and indirect areas. Largest use will probably be in resolving conflicts in sensor data.

B. To what products or processes might it be applied?

Robotics, and other shop floor activities. Some also in non-touch labor areas.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Improvements in flexible manufacturing capability will allow more weapons for less cost.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Could help maybe in battlefield management, autonomous vehicles, SDI

REPORTER: Reimann

AIDED BY: all members

TECHNOLOGY: DECISION SUPPORT SYSTEM FOR MANUFACTURING DECISION MAKING (e.g., FOR EFFICIENT TASK ASSIGNMENT AND EFFICIENT PROCUREMENT PROCEDURES) [L-18]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Intelligent information handling systems are emerging in the manufacturing environment. These systems will optimize output of future manufacturing systems by increasing the volume accuracy, and timeliness of information required to coordinate all of the interrelated manufacturing activities including: planning, scheduling, control, operations, quality control, ...etc.

Automotive industry, appliance manufacturers, and other high volume producers have their own versions of decision support systems--these may have been optimized for certain product lines but are not universal in nature--leaving problems for job shops with a more general decision support problem.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Large scale application is dependent on high speed/low cost computers and "user-friendly" software, and the development of a standard universal model for a manufacturing decision support system.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1990-1995

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Japan is undoubtedly ahead in the application of this ET. Japanese government and industry have a better track record in cooperating on this issue. In the US, government/industry effort is limited to relatively small investment at National Bureau of Standards Advanced Manufacturing Research Facility, and other small programs, e.g. Navy and the Air Force Manufacturing Technology Program.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Opportunities for improved cost of manufactured goods, improved military readiness desire to increase market share--all of these will drive this technology. Potential Payoff is enormous when life cycle costs are considered (e.g. reduction of inventories by using Parts on Demand Concept).

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Production and Procurements of all manufactured products used by military.

Not product specific.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Impact would allow higher degree of readiness for the same investment or the same amount of readiness for a reduced investment.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Complete and successful development of this ET would be synergistic with the other developments in factory automation: robotics, AI, adaptive controls, etc.

REPORTER: J. W. Walters

AIDED BY: all members

MANUFACTURING

TECHNOLOGY: "MUSCLE-LIKE" MECHANICAL ACTUATORS [L-21]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

This technology is concerned with the development of mechanical actuators which are made up of bundles of fibers which change in dimension upon the imposition of an electric current--much the same way as a human muscle.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Advanced Control Theory
  - Non linear controls
  - Adaptive controls
- Miniature electric (miniaturized transducers and microactuators)

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Univ. of Utah funded by DARPA is working in the area. It is not clear when this technology would be available for inclusion into the production process.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

Unknown

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Need for increased robot performance; speed accuracy, repeatability accompanied by need for improved reliability and increased strength to weight ratio.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1990	US Japan Ger
2. First Experimental Device application (or first experimental process demonstration)	1995	US Japan Ger
3. When available for inclusion in product or process?	2000+	"

3- APPLICATIONS

manufacturing
Describe the potential ~~military~~ applications of this ET:

A. How might it be used?

Successful implementation of this technology would mean an entirely new family of robotic arm which would be more simple than the present day systems actuated by electric motors, various intermediate drives and subassemblies. This system would be much more reliable than present systems. Also their speed of response, acceleration (if like muscle) could be a 100 times better than conventional actuator systems and consequently overall robot performance will be far superior.

B. To what products or processes might it be applied?

All robotic applications

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

These robots could increase the applicability of robotics in manufacturing of military systems and improve overall productivity of such. For example, it is more likely that they could be used aboard ships as the heart of flexible manufacturing systems for making needed parts on a demand basis. (Present concepts call for land based manufacturing systems.)

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

* Development of android soldiers.

* SDI applications.

REPORTER: J. Sheehan

AIDED BY: Group

MANUFACTURING

TECHNOLOGY: AUTOMATIC UNDERSTANDING OF SPEECH OF A SPECIFIC INDIVIDUAL [L-6]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Automatic speech recognition is a tool that would enable a specific individual to enter information into a system that would affect the manufacturing process. This input could be data, instructions, or a decision. The technology is particularly useful in those situations where the operators hands and eyes are already very busy.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Before this technology can be successfully implemented, there will need to be substantial improvements in low cost computing power (100x). There is need for better ways to "describe" (i.e. to numerically characterize) a given word or collection of words. This improved description will need to be more tolerant than current algorithms to changes that occur from day to day, or minute to minute, in a person's speech pattern.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

1995 - Some fragile systems are commercially available and in use today. Marginal improvements may evolve slowly, but wide-spread application must await quantum leaps in fundamental understanding of the speech recognition process.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

We are the leaders. Some work in Europe and Japan. Some speech recognition systems have been flight tested in F-16 aircraft.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military need for a pilot's assistant will be the driving force. Other opportunities will be ship-board command.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Done	US
2. First Experimental Device application (or first experimental process demonstration)	Done	US
3. When available for inclusion in product or process?	Done (limited)	US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

In manufacturing, it mignt be used for inventory control (37 widgets, 14 thing-a-ma-bobs) "training a robot," conveying a quality-control decision. In maintenance, it could be used in connection with an instruction set or check list to indicate conclusion of a step or to report on the condition of a part or system.

B. To what products or processes might it be applied?

Not product specific

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Improve manufacturing productivity

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Major military applications would be in areas other than manufacturing e.g. C^3, pilot's assistant.

REPORTER:

AIDED BY:

MANUFACTURING

TECHNOLOGY: AUTOMATED CHEMICAL ANALYSIS USING ROBOTICS, FOR LABORATORY OR MANUFACTURING PLANT [L-3]

1- DESCRIPTION

A. Describe the emerging technology in <u>quantitative</u> rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The use of automated chemical analysis using robots in a manufacturing environment opens to possibility of process and quality control in hazardous and/or clean systems with improvement in quality, cost, safety all possible. Retraining literally becomes reprogramming. The concept has been demonstrated and developed in the analytical laboratory; the breakthrough is a broad based application in a manufacturing plant.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

This technology is an integration of at least four basic areas: 1) robotics, computers, sensors and chemical analysis, and will depend on developments in each of them. The existing "laboratory-grade" robots will need to become industria grade. The improvements in computer speed and capacity, at low cost, will allow the development to go forward. Reliable sensors, providing information usually generated by humans, are required to allow improved quality and reproducibility of measurement. Perhaps most important are new chemical analysis techniques, design with automation in mind, rather than the "robotizing" of classical analytica methods.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

The principle has been well demonstrated in the laboratory (e.g. Zymate, see the May Atlantic City conference*), the demonstration in a real manufacturing environment requires only a decision and should be done in 1985-90.

* Scientific Computing & Automation Conference & Exposition (May 1-3, 1985).

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

In any question of robotics, the Japanese position must be recognized. However, in automated chemical analysis there is also much good work in Europe.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This technology is broadly applicable and although there is government involvement (e.g. ONR, NBS, LLL) the main drive is industrial. This is true both of industries with an identifiable need (e.g. automobiles and semiconductors) and of the producer industry (e.g. Zymate and Perkin-Elmer).

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980 -1985	Zymate & others
2. First Experimental Device application (or first experimental process demonstration)	1985 -1990	Semi-conductors probably
3. When available for inclusion in product or process?	5 years	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The non-manufacturing uses (e.g. chemical warfare) are obvious and will be dealt with elsewhere. In manufacturing, any process that could make use of inexpensive, on-line, real-time chemical analysis would benefit: welding, semi-conductor manufacturing, chemical production come to mind.

B. To what products or processes might it be applied?

See above, processes which are hazardous on which require clean-room conditions would be obvious candidates.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Improved product quality and manufacturing safety. Reduce costs.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

This directly links to the "expert systems" concept and would benefit from developments of sensors, robots, and computers. The development of microchemielectronic integrated devices, including sensors, microprocessors and chemical analysis capability on a chip, as has been pioneered by J. Ruzicka of Denmark are particularly important to this technology (see e.g. Analytical Chemistry 55, 1040A 1983)). This is addressed as ET #G-2.

REPORTER: Ron Fleming

AIDED BY:

MANUFACTURING

TECHNOLOGY: ARTIFICIAL INTELLIGENCE APPLICATIONS IN MANUFACTURING [New]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Applications of Artificial Intelligence (AI) to the full spectrum of manufacturing problems has the potential for a tremendous impact. Current typical AI rates vary from 10-100 rule inferences per second (RIPS) which is compatible with decision time frames for simpler manufacturing processes. Projected gains in AI over the next several years will provide capabilities to handle more mfg areas. Throughout manufacturing, and in particular in areas of planning, scheduling, etc., human experts are relied on to control most of the activities.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Key advancements will be required in knowledge acquisition and knowledge representation, architectures for control, process kinetics, combination of numerical and symbolic processing, high speed and high capacity computers, process modelling, sensor fusion, etc.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Currently available for very limited areas, e.g., expert systems. Broad based applications are 10-15 years away.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

Very few applications of AI in mfg exist anywhere. US may be in the lead in terms of planning for research, e.g. USAF Manufacturing Science program plans to create a major research "Institute for AI in Manufacturing" and DARPA's planned new initiative in "Intelligent Processing"

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Reduced numbers of skilled people in manufacturing ability to reliably produce increasingly complex systems, need to reduce cost of flexible manufacturing, need for real-time control, and operation of an uncertain environment.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Now	US limited
2. First Experimental Device application (or first experimental process demonstration)	-90	US Japan
3. When available for inclusion in product or process?	-95 to -2000	US & others Broad based

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Has the potential to revolutionize the entire manufacturing environment, from all aspects of mfg from shop floor, to mfg systems, to information handling.

B. To what products or processes might it be applied?

Not product or process specific.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Dramatic improvements in manufacturing will allow more military systems at the same cost or lower cost systems. Improvements in readiness, quality, reduced logistical requirements will all contribute to improved military capabilities.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Autonomous Land Vehicle
Pilot associates
Battlefield management

It is believed the manufacturing applications of AI will lay the ground work for many other applications since the timeframe for AI in manufacturing is nearer term than most other DoD projected applications.

REPORTER: V. J. Russo & P. A. Parrish

AIDED BY: all members

TECHNOLOGY: PRECISION ENGINEERING [New]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The achievement and maintenance of micro-inch and sub micro-inch tolerances in machinery forming and assembly operations.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Required related technologies include real time sensors, micropositioning control elements, control systems and algorithms appropriate to the fine tolerances, process models to facilitate the process control, and tools (i.e. cubic boron nitride cutters, etc.)

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

By 1990-- Capabilities are currently in the laboratory, 3-5 years for production capability. Demonstrated for some special environments (not cost limited), otherwise not generally.

B. Estimate US status compared to any non-US work being done on the ET in question/or its inclusion in a (ours and theirs) defense system.

Extensive effort has been ongoing in Japan and western Europe--we are behind 3-6 years.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Military needs for quieter more reliable systems. Laser optics needs.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Done	
2. First Experimental Device application (or first experimental process demonstration)	1985	
3. When available for inclusion in product or process? * earliest date with accelerated funding	*1990-2000	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Precision forming is crucial in optics, bearings, gyros etc. In addition the ability to precision machine can increase equipment lifetimes and reliability by factors of 2 and greater.

B. To what products or processes might it be applied?

Any machinery or grinding process.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Quieter submarines and ships, more reliable rotating machinery in ships and aircraft, and new optical capabilities.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

General reliability improvement and life cycle cost reduction. Possibly an enabling technology for Beam weapon systems envisioned by SDI.

REPORTER: W. Schmidt

AIDED BY:

TECHNOLOGY: NEUTRAL PARTICLE BEAMS [illegible]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Devices for production of neutral particle beams are under development. This effort represents emerging technology with applications for national defense. The beams produced consist of hydrogen or other low Z atoms at current equivalents of about 100A, energies in the several hundred MeV range, and beam durations of a fraction of a second. The composite devices include prime power sources, ion sources, accelerators, and mechonisms for neutralizing and launching the beams.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Prime power and power conditioning is covered by the "Prime Power" element.
2. Ion sources - higher current and lower emittance sources must be developed
3. Accelerators - development of substantially more compact and lightweight accelerating structures that would produce several 100's MeV beams.
4. Neutralizers - development of devices to neutralize the ion beam without increasing the emittance; such ideas as use of lasers for photodetachment might provide the necessary methods to accomplish this task.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Major development of the neutral particle beam technology is carried out at LANL:

a. ground demonstration at 50 MeV - 1990
b. space-qualified prototype - 2005

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

The major effort is in US, as far as known.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

SDI program will drive this technology

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Early 1970's	LANL
2. First Experimental Device application (or first experimental process demonstration)	1990	LANL
3. When available for inclusion in product or process?	Weapon in 2005	SDI

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Discrimination of RV vs. decoys
2. ICBM kill

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Significant increase in effectiveness of US defense capability against nuclear attacks.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Complements other SDI systems.

REPORTER: I. Vitkovitsky

AIDED BY: P. Debenham

M. H. Cha

DIRECTED ENERGY

TECHNOLOGY: COHERENT LOCKING OF LASER BEAMS [illegible]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- Injection locking of 100 watt average power excimer lasers demonstrated with master oscillator injected powers of mwatts. Locking of several diode lasers using a single master oscillator achieved.

- Evascent wave coupling of a 40 element diode laser array demonstrated; also coupling of 4 CO_2 waveguide lasers via inter-cavity radiation exchange.

- Shown that phase conjugate resonator mirrors or intra-cavity non-linear dispersive element greatly reduces phase/frequency locking sensitivity to resonator length mis-match.

- There is every reason to believe that present laser phased-array/resonator coupling techniques could be extended to allow beam steering/slaping by controlling the phases of the individual elements.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Acquire a clear basic understanding of the physics involved in the various resonator coupling/phase-locking schemes.

- Develop technology for the production of arrays of small, independently addressable phase modulators for wavelengths from near U.V. to 10μ.

- Identify and produce high quality non-linear/phase conjugation optical materials.

- Fast response feed-back electronics and actuators necessary for matching resonator lengths.

- Inexpensive methods hardware needed for monitoring laser output frequencies (and phase) with high accuracy ($\sim$1 MHz)

- Fabrication techniques for large, two-dimensional arrays of lasers of various types (10^2 - 10^4 elements, excimer, CO_2, solid state, injection lasers).

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

Phase locking of linear diode laser arrays already demonstrated by Spectra Diode, Cal Tech, MDAC, and other. Phase locking of 2-4 CO_2 waveguide lasers achieved by UTRC and WJSA. Former ready for utilization in 2-3 years, latter in 5 years. Injection locking of single 100W excimer laser demonstrated; expansion to locking of several lasers by common master oscillator appears straightforward (~ 2 years). Extension to multiple, high power devices should occur within 5 years.

B. **Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.**

° US far ahead of allies in ET area (since latter have invested little money).
° Japanese rapidly catching up in phase lock diode laser array area. Have recently launched upon a major national effort.
° Status of Soviet Bloc cannot be assessed. No open publications re high power laser scaling.

C. **What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

Optical data recording/retrieval industry has promoted phase locked diode laser arrays--require higher power than is available from single device. Phase locking of several high power laser apertures appears to be critical for SDI weapon and coherent combination of lower power laser devices highly desirable for many surveillance, acquisition, and tracking applications. Industrial processing needs will also drive phase locking technology (especially for solid-state lasers).

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980-84	US Private Industry
2. First Experimental Device application (or first experimental process demonstration)	1987	US Navy DARPA
3. **When available for inclusion in product or process?**	early 1990s	US Industry Military

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Coherent combination of high power laser outputs for SDI and other military weapons applications
- Facilitate the rapid directing of optical beams for SDI SATKA as well as for other reconnaissance and surveillance applications.
- Allow coherent laser outputs to be scaled to levels useful for military communications (e.g., for networking of SDI C^3 satellites).
- Allow high power intermediate output power surveillance and communication system to operate with very narrow output bandwidths → significant decrease in required output power.

B. To what products or processes might it be applied?

- Welding/cutting for manufacturing (e.g., autos, boats, aircraft)
- Data storage/retrieval devices
- All products/processes involving low cost, modest power highly coherent radiation (10-100 watts) or high peak/average power radiation with reduced coherency (1-100 kw).

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Coherently combining outputs from several high power lasers absolutely essential for a space based SDI laser weapon
- Beam director problem is considered to be the most difficult one associated with SDI. SATKA via optical radar-phased laser arrays could provide solution.
- There are a multiplicity of military surveillance/communication problems that require low cost, compact solid state laser sources with output powers that are reachable via phase-locked diode laser array technology (i.e. 10-50 watts)

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: M. B. White

AIDED BY:

DIRECTED ENERGY

TECHNOLOGY: NON-LINEAR PHASE CONJUGATION TECHNIQUES DE-14[illegible]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- Non-linear optical phase conjugation using SBS and degenerate 4-wave mixing shown to be capable of correcting optical beam distortion (both within and outside laser cavities).
- ET can also be used to facilitate matching/locking of laser resonators and for coherent combination of laser beams.
- Exotic techniques (e.g. 2-wave mixing in photo-refractive materials and "scalar phase conjugation) applicable to wide variety of applications including transmission of images through optical fibers and fiber optic rotation sensing devices.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Non-linear optical materials/techniques that are useable at high average optical power.
- In some cases, scientific understanding of basic physics involved is incomplete.
- Materials--High power handling for SDI
  --High sensitivity for low power devices

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

° Phase conjugation of 1-10 J optical pulses using SBS already demonstrated by HRL, TRW, NRL, etc.; implementation for military purposes in 3-4 years possible.

° Phase conjugation via 4-wave and 2-wave mixing demonstrated at low powers; severely limited by available materials. Useful implementation in 5-10 years possible.

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

° Soviets pioneers in SBS phase conjugation; continue to be leaders.

° Soviets probably not as far along as US in using other processes. Efforts to scale to higher power not revealed.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

° High power laser beam clean-up for military applications as well as for industrial processing

° Low cost devices (e.g. rotation sensors) based upon injection laser technology

° Classified tactical surveillance and EOCM applications.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	SBS-1970 SBS-1975 FWM-1975	Soviets US (Hughes Res, Bell
2. First Experimental Device application (or first experimental process demonstration)	SBS-1987 FWM early 1990's	US(SDIO) US(SDIO &Tactical Sys.)
3. When available for inclusion in product or process?	SBS early 90s FWM mid 1990s	US Industry "

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- High power laser beam clean-up and combining for weapon applications
- Alleviate pointing and optical quality requirements for laser weapons
- Inertial guidance systems (rotation sensors) and component for optical data processing (SDIO C^3/battle management)

B. To what products or processes might it be applied?

- Industrial lasers
- Optical computers
- Inertial guidance systems

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- Beam clean-up critical for most military applications of high power lasers (SDIO, EOCM, etc.)
- Significantly alleviating large-optics beam pointing and optical quality requirements→great cost reduction for space-based laser systems
- Could greatly simplify and increase effectiveness of classified EOCM systems
- Provides "new knob" for all military optical systems (e.g. lossless beam splitters, insensitivity to optical distortions and mis-alignments, etc.)

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: M. B. White

AIDED BY:

TECHNOLOGY: FREE ELECTRON LASERS FEL TF-131

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

High current FEL devices can, potentially, provide IR/visible highly collimated beams at power levels of 5-10 MW. Their potential advantage is high efficiency of light output. These devices require prime power sources, high current density ($\geq 10\ A/cm^2$) electron guns, accelerators operating at current levels of the order of 10kA and electron beam-laser interaction cavities.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Prime Power-- covered by the Prime Power Element
2. Electron Beam guns--these serve as injectors into the accelerator. Lower emittance is needed (improvement of the order of x10); the injectors must be capable of repetitive operation at high frequency (10-100 kHz) and (in conjunction with power conditioning systems) must provide longer pulse duration.
3. Accelerators--demonstration of repetitive operation at 10-100 kHz rates. In case of space applications, such accelerators must be reduced in size and weight by large factors.
4. Cavities--the power density ratings at optical mirrors must be increased by order of magnitude, to provide systems with practical scale.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

For ground-based operation--2000
For space-based operation --2010

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

Some work appears to be going on in Soviet Union on high current FEL's.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

SDI ground and space based systems.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1970s	Madey Pellegrini
In IR region: 50 MeV 10 kA 1 kHz 2. First Experimental Device application (or first experimental process demonstration)	1986	LLNL
3. When available for inclusion in product or process?	2000	SDI

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. ICBM kill
2. Satellite sensor kill

B. To what products or processes might it be applied?

To SDI systems

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

This technology will enhance the national defense capabilities in relation to ICBM's.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

It complements other SDI systems.

REPORTER: P. Debennam

AIDED BY: I. Vitkovitsky

TECHNOLOGY: METAL MATRIX COMPOSITES FOR SPACE STRUCTURES [I-6]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

In the laboratory, metal matrix composites demonstrate the potential for high specific stiffness, excellent dimensional stability, and superior survivability compared to conventional structural materials.

B. List and describe related manufacturing know-how keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Improvements in fiber/matrix interface coherency and stability by fiber processing technology development present the opportunity for exploitation of metal matrix composites. Significant work is required in processing, fabrication, and manufacturing technology to produce tailored directional properties and complex structure shapes.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

5 years

B. Estimate US status compared to any non-US work being done on the ET in question, or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

SDI Requirements

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Improved space structural material requirements include high specific stiffness and/or strength, dimensional stability, high damping, manufacturability/deployability and survivability. Secondary characteristics may include low contamination, thermal control, and RAM/RAS.

B. To what products or processes might it be applied?

Large radar antennas
Large DEW device platforms
Acquisition, pointing, tracking, and control platforms
Aircraft

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Improved Space Structural Materials are mission enabling for many SDI applications.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Expanded utilization of metal matrix composites will lower procurement costs enhancing the applications both in military and civilian arenas.

REPORTER: ______________________

AIDED BY: ______________________ ______________________

DIRECTED ENERGY

TECHNOLOGY: SHORT WAVELENGTH LASERS (NON-NUCLEAR) [illegible]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Requirements:	Wavelength Region:	~ 10-2000 Å	(exact requirements
	Efficiency:	10^{-3} to 10^{-2}	will depend on use
	Energy Flux:	1 Joule/cm^2	--i.e. weapons on SATKA)

The proof of principle for X-Ray lasers has been accomplished in the past year. High gain ($\gtrsim$ 100) in the 100-200 Å region has been obtained at Livermore and Princeton, using Nd-glass and CO_2 laser pumping, respectively. To be useful in SDI applications, X-Ray lasers must be scaled up considerably in efficiency, energy, and reliability. The Princeton experiment, done on a small laboratory scale, is a step in this direction.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

To obtain the required efficiency and energy, an X-Ray laser scheme without laser pumping must be developed. This will likely involve flashlamp or discharge pumping. UV lasing with flash lamp pumping has been obtained by the Silfvast group at Bell Labs, and scaling to the soft X-Ray region is predicted within the next year. High efficiencies (10^{-3} to 10^{-2}) are predicted. Most of the long term development will be in reliability and scaling up the energy.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

SATKA applications: 1995-2000
Weapons applications: 2000-2010

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this techno'ogy (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

X-Ray lithography; high resolution electron etc ng
medical applications
physical science applications (spectroscopy, crystallography, etc.)

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1984	LLL(Novette) Princeton
2. First Experimental Device application (or first experimental process demonstration)	1995	
3. When available for inclusion in product or process?	2000	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

A) SATKA
B) antiballistic weapon

B. To what products or processes might it be applied?

Large scale atmospheric diagnostics
Laser weapons for inflicting fatal damage to missiles or their electronics, or to space satellites or weapons.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

SDI applications require fast, high energy beams that are difficult to interrupt and easy to aim and focus. Directed energy in the form of coherent short wavelength radiation is one of the prime candidates to fulfill this need.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Communications and logistics, by developments in optics, lithography & etchings, electronics, ability to destroy electronics, generate noise.

REPORTER: D. E. Kelleher

AIDED BY: M. J. Clauser

TECHNOLOGY: PRIME POWER

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The most demanding requirement is for 100 MW systems storing GJ-level energy. The prime power systems must be compatible with use in space (e.g., thermal management). The approaches to developing such systems include rotating machinery (homopolar generators, alternators), batteries and chemical storage (explosive generators).
There are other less demanding requirements that can be met with other approaches, such as nuclear reactor generators.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The key problems associated with use of batteries is the need to release energy faster then currently possible, as well as to store at higher energy density. The rotating machinery also must be more compact. In addition, reliability and life-time need substantial improvement. Such issues as vacuum welding, seals and other issues related to space environment must yet be investigated. A repetitively pulsed or reusable explosive generator must be developed.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Few MW generators--1995
100 MW GJ systems--2005

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

Substantial amount of related work is going on throughout the world. Soviet technology related to inductive storage and explosive generators appears to be ahead of that in US.

C What needs/opportunities will drive this techno gy (e.g., costs, military, industrial, consumer, environmental, etc.)? Be s specific as possible.

Material development for advanced batteries wou : have broad impact.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	---	---
2. First Experimental Device application 100kW nuclear reactor (or first experimental process demonstration)	1990	DoE
3. When available for inclusion in product or process?	1995	SDI

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Prime power would be used for powering the Directed Energy weapons and would serve also for powering auxiliary systems such as tracking, communication and house-keeping.

B. To what products or processes might it be applied?

Prime power development would allow placing into space non-nuclear weapon systems for ICBM and satellite kills.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Prime power is the necessary component of all space based defense systems. Directed Energy Weapons have special requirements which can be potentially met by emerging prime power technologies.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

This is a highly interdisciplinary field. Any advances in prime power would impact areas such as ASW, tactical weapons, ship design, and others.

REPORTER: I. Vitkovitsky

AIDED BY:

DIRECTED ENERGY

TECHNOLOGY: ARTIFICIALLY STRUCTURED MATERIALS FOR PULSE POWER SWITCHING

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

1. Gas mixtures with drift velocities and attachment rates tailored to be partial functions of (E/N)

2. Heterojunction and semiconductor materials (potential not tested).

3. Artificially structured surfaces for electron emitters.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

1. Large scale production is no problem with current concepts. Part of developing technology is optimization of materials.

2 & 3. MOCVD, molecular beam epitaxy, implantation techniques.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

It is not clear that the proposed parameters can ever be attained.

1. 4-6 years (technology maturity)
2. 10 years (technology maturity)
3. 6-8 years (technology maturity)

B. Estimate US status compared to any non-US work being done on the ET in question or its inclusion in a (ours and theirs) defense system.

1. Technology is easy to replicate (US/USSR)

2 & 3. This is hard to estimate since these are embryonic.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

1. Military
2. Military (the many drivers for this technol y outside military will have negligible impact on military requirements.
3. Military, industrial

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	?	?
2. First Experimental Device application (or first experimental process demonstration)	?	?
3. When available for inclusion in product or process?	95	?

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

These technologies are for opening switch technologies.

B. To what products or processes might it be applied?

1. Particle beam weapons
2. Particle beam fusion
3. Weapons simulation/vulnerability studies.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

If there is concurrent progress in this technology and those noted in 3-B, considerable potential exists with regard to defensive weaponry.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

The weapons (directed and kinetic energy) must also undergo concurrent development. Kinetic energy is most likely to reach an "operational" stage, but for operations in space heat transfer and electrical breakdown are still significant problems.

REPORTER: Bobby Junker

AIDED BY: Ron McKnight

DIRECTED ENERGY

TECHNOLOGY: X-RAY - NUCLEAR DRIVEN

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The DoE is conducting research on X-RAY lasers driven by nuclear explosive devices. These devices have potential applications to strategic defense as ICBM interceptor above the atmosphere. All further information in "Description" and "Status" is classified as Restricted Data, much at the Secret level.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

B. Estimate US status compared to any non-US work being done on the ET in question, or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

An XRAY laser pulse of sufficient intensity could be capable of:

a. destroying ICBM boosters on post-boost vehicles
b. disabling or destroying optical elements of satellite-based surveillance systems and laser weapons.

B. To what products or processes might it be applied?

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

If we develop it, it could play a significant role in our strategic defense system. If they develop one, it could pose a serious threat to elements of our strategic defense system as well as to our offensive systems.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: M. J. Clauser

AIDED BY:

TECHNOLOGY: ELECTRON BEAMS

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

High power electron beams are being developed which appear to have significant promise for strategic defense applications as weapons and as decoy discriminators. The ATA* accelerator at LLNL and the RADLAC Accelerator at SNLA are operational, and can be used for studies of electron beam propagation. Closely related research at LLNL, SNLA, and NRL has demonstrated that laser-generated ionized channels can efficiently guide electron beams, with applications to beam transport in accelerators.

* Advanced Test Accelerator, 50 MeV, 10 kA nominal

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

light weight, efficient lasers
light weight, compact high energy electron accelerators
beam steering

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technical feasibility of one application can be demonstrated by 1995 with adequate funding, for other applications, by 2005 may be possible.

B. Estimate US status compared to any non-US work being done on the ET in question, or its inclusion in a (ours and theirs) defense system.

The RADLAC technology was based on Soviet research
ATA is not known to have a Soviet parallel

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

missile, RV intercept
discrimination of decoys

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	~1984	SNL LLNL NRL
2. First Experimental Device application (or first experimental process demonstration)	early to mid 1990s	
3. When available for inclusion in product or process?	mid 1990s?	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Terminal Defense against missiles
Discrimination between RVs and decoys
Booster, PBV kill (Post-Boost Vehicles)

B. To what products or processes might it be applied?

The use of ionized channels for electron beam transport may make lightweight, compact accelerators practical.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

1. Speed-of-light weapon for terminal defense
2. Portable, perhaps satellite-based high-energy accelerators will become practical for Strategic Defense

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Provide discrimination of decoys for KEWs and other weapons.

REPORTER: M. J. Clauser

AIDED BY: M. H. Cha

TECHNOLOGY: ADIABATIC DIESEL ENGINE TECHNOLOGY [C-3]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The technology includes an understanding of high-temperature (using ceramics/composites/metal alloys) diesel engine combustion, friction, lubrication, and wear. A major objective of this technology includes minimization of heat loss (near-adiabatic), thereby drastically reducing cooling system requirements and permitting improved compactness, fuel economy, reliability/maintainability, and survivability.

Research advances in 1) high temperature materials, 2) high-temperature friction and wear phenomena, 3) unconventional lubrication techniques (including solid lubricants--both in slurry and surface coating form), and 4) adiabatic heat transfer phenomena identification have allowed advanced versions of adiabatic engines to become an emerging technology of note. In addition, recent research within the NDE flow detection area, such as photo acoustic microscopy provides an opportunity for materials processing improvements, particularly in the area of brittle high-temperature materials.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Areas of need required for translation of this technology to large-scale (or limited) production includes: 1) improved materials processing (of ceramics --both monolithic and coating versions--and composites), 2) improved and more reliable component NDE inspection techniques, 3) methods of reducing high-temperature material application costs (such as applying a ceramic coating to a high temperature engine component), 4) methods of producing high-temperature lubricants in a repeatable and economically feasible manner, and 5) improved advanced materials analysis methodologies.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. **Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).**

At extremely high-levels of power output, compactness and surface temperature, the technology will be available for advanced military vehicles in approximately 1990. The quantitative levels of these factors are classified and cannot be discussed here. Early versions (low output-100 BMEP) are technically available now, and have begun to be put in production by the Japanese and the Germans. In the US, early versions of the adiabatic engine were pioneered by the US Army TACOM (1979-83)

B. **Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.**

It should be noted that the technology has begun to be applied in an aggressive manner by Japan (in automobile engines--pistons, exhaust parts) turbochargers, cylinder heads) and by Germany (ceramic exhaust port in production on all 1985 944 turbocharged engines). These early spin-offs of adiabatic engine technology do not approach the level of technology projected to be available to the US within this emerging technology; however, it does show a complementary commercial (early spin-off) military application route which should aid in driving the technology for both domestic and military applications.

C. **What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.**

The technology will continue to be driven by a combination of military need and commercial "early-spinoff" payoffs. Cost reduction including both material and manufacturing remains an area for future effort. In addition, the commercial US market place will continue to pursue "early-spinoff" versions of adiabatic engine technology, simply because their international competitors (Japan and Germany and others) are beating them to the punch.

D. **Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.**

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	Classified	Classified
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The emerging technology is generic and applicable to a wide range of military vehicles (from low risk (trucks) to future main battle tanks). In addition, the Navy has begun to examine the technology for surface ships (diesel powered), and NASA--Lewis is involved in studies of advanced reciprocating (radial engine) adiabatic engines for commuter aircraft. The Army (AVSCOM) has begun a major program in this area for possible use in advanced helicopter applications.

B. To what products or processes might it be applied?

Application to a wide spectrum of products in a realistic projection for this emerging technology. The technology has applications within a broad range of engine components including: pistons, liners, cylinder heads, exhaust parts, intake parts, turbochargers, and valves. The processes of technology application include monolithic ceramics, ceramic coatings, composites, and high-temperature metal alloys. Potential uses are military ground vehicles (tactical and combat), helicopters, ships, commuter aircraft, domestic rail, generator sets and automotive passenger cars and trucks.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Adiabatic Engine technology offers the opportunity to produce quantum improvements within military ground vehicles (both tactical and combat) in a number of areas including: 1) compactness, 2) fuel economy, 3) weight reduction, 4) RAM-D, 5) signature reduction (noise, smoke), 6) multifuel characteristics, and 7) design flexibility.

In expanding these factors:

1. Compactness: In an armored combat vehicle (i.e., tank), approximately 40% of the underarmor volume is taken up by the propulsion system (which includes engine, transmission, cooling system, fuel, air filtration system). It is estimate that over ½ of this 40% volume could be made available for other purposes (ammunition, fuel, etc.) if an advanced technology version of an adiabatic engine were implemented. Conversely, the vehicle size could be greater reduced (other things being equal), through the use of this technology (impacting power/weight ratio and agility, cost, and survivability.

2. Fuel Economy: It is estimated that an advanced adiabatic engine version incorporation within a tactical combat vehicle could increase its range (fuel economy) by 30-50% (when compared to a conventional diesel engine and of course more when compared to a gas turbine).

(continued Page 5)

B. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

Again, generically the technology is applicable over a wide range of vehicles (ground (tracked and combat), ship, and limited air applications). The factors discussed in 4-a Impact can imperfectly be extrapolated to water and ship applications.

REPORTER: W. Bryzik

AIDED BY: Ed Lenoe

ADIABATIC DIESEL ENGINE TECHNOLOGY cont'd

4-IMPACT (cont'd)

A.
3. Weight Reduction: Weight reduction of total propulsion system weight by approximately 30%.

4. RAM-D: Currently over 50% of the failures of Army combat vehicles are related to the cooling system (hoses, radiator, fans, pumps, low water level, etc.) The virtual elimination of the cooling system offers an excellent opportunity to improve RAM-D through the use of an advanced adiabatic engine.

5. Signature Reduction: Conventional diesels are loud and have smoke problems. High-temperature "near adiabatic" combustion reduces ignition delay (peak combustic pressure and knock limit) and thus sound and smoke (more complete and rapid burning). Preliminary experimental simulations of advanced adiabatic engines have shown smoke reductions of up to 80%, and noise reductions of over 30%.

6. Multifuel Characteristics: Adiabatic combustion characteristics favorably impact multifuel characteristics (early simulations show adequate burning with diesel, the JP's, and gasoline fuels).

7. Design Freedom: Designing combat vehicles with 6 inch ballistic grills for cooling air intake and exhaust, for example, is not a great survivability "plus" on current combat tracked vehicles. Eliminating such cooling requirements allows designs of armored tracked vehicles to be considerably more survivable in battle.

TECHNOLOGY: ENGINES WITH LOW IR EMISSIONS [C-9]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The emerging technology encompasses innovative manipulation of the thermodynamic cycle (from a preliminary or first design consideration). Development of cooling/heat transfer concepts without penalizing the cycle, and use of IR absorbing materials, thin film cooling, obscuration, selective emissivity coatings and other technology. Quantitative parameters and trending are classified.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Many diverse technologies are utilized in an engine exhaust suppression system e.g. thermodynamics/ air flow modelling, hardware designs, coating development, high performance insulation, etc. Needed related materials include lightweight heat absorbing, and dispersing and high temperature un-cooled non-metallic material Design and manufacturing capabilities are needed for controlled and targeted variability of quenching airflow. Variable controlled cooling also requires a sophisticated FADEL-type propulsion system control with sensors and feedback on effectiveness.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Partial material development and application and acceptable (practical) cycle cooling flow variability and control measures are available.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Cycle variability for performance optimization is presently being developed within the services. Foreign on/off cooling schemes are being assessed by FTD, NISC, FSTC, and NAPL. US manufacturers are developing concepts in preliminary designs but Helo suppressor development remains the common approach.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

DoD needs for survivable and available weapons systems will drive this technology. It must be used during the vehicle design stage to "design in" IR exhaust system.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE		YEAR	BY WHOM
1. Proof of scientific principle demonstration	Partial materials, cooling, concepts, cycle variability	1980	DoD & Industry
2. First Experimental Device application (or first experimental process demonstration)	Classified		DoD & Industry
3. When available for inclusion in product or process?	Classified		DoD & Industry

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

This technology would be used with materials being developed for multispectral signature reduction for the entire vehicle, while this low IR engine technology would be applied to the most significant IR source on the vehicle.

B. To what products or processes might it be applied?

Air, land and sea surface power plants and propulsion systems.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

This technology will significantly reduce the threat created by State-of-the-Art sensor and lock-on concepts (available worldwide), to Helos and low altitude, low mach no. fixed-wing A/C. This technology will further improve our current capability to minimize IR signatures for rotary wing aircraft without the present adverse impact on performance. It will also provide the technology to control or design out these emissions. There is currently no acceptable add-on device for missiles, rockets, fighter/attack or patrol aircraft and this technology will type of product improvement.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The use of this technology with signature reduction materials for the remainder of the combat or support vehicles is a synergistic system. The result is a low IR land, air and sea surface vehicles which are much more difficult to detect [illegible] identify. The overall increase in vehicle survivability enhances force effectivenes

REPORTER: Wagner

AIDED BY: Benn

Mick

MOBILITY

TECHNOLOGY: FUEL CELLS FOR VEHICLE PROPULSION [C-18]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

The use of fuel cell technology for vehicle propulsion has become possible to consider in a realistic sense only in the very recent past. Power densities which support propulsion are achievable in the laboratory in small cell sizes. System designs for upscaling have identified the specific technological issues, and proposed approaches for the solution of each now existing. The principal issues include catalytic conversion of fuel, fuel processing to achieve required power densities, fluid flow to achieve efficiencies predicted, utilization of low-cost alternative materials, and operating regime limitations. Fuel cell technology effectively circumvents cycle inefficiencies and, in some versions allows for propulsion system efficiencies of 55% or more. Variants deemed possible for vehicular applications in one respect or another include the phosphoric acid, molten carbonate, solid oxide and proton exchange membrane variants. Each version has demonstrated the ability to achieve the power densities for each technology range from a low of 200°C for the proton exchange membrane variant to a high of 1000°C for the solid oxide version.

For vehicular propulsion applications, the operating regime requires consideration of the following requirements: rapid, ambient temperature start; ability to handle rapid transients driving acceleration/deceleration; composition of system (cont next pa

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

The equipment, knowledge, and materials needed to prepare an initial prototype are available now, and could result in such a prototype within two years. As indicated in 2. d, a militarily significant product could be developed by 1990.

FUEL CELLS FOR VEHICLE PROPULSION cont'd

1-DESCRIPTION (cont'd)

A.

operation byproducts, and ability to accept frequent operational cycles. Of the technologies described above, the proton exchange membrane offers the greatest promise, and should be explored as the first option.

Membrane technology available today for the proton exchange membrane variant is effective, but costly. Low cost membrane with cost reductions from $\$40/ft^2$ to $\$1\text{-}2/ft^2$ are emerging from other commercial research. In addition, the use of non-noble metal catalysts offers reductions of up to a factor of 16 in the use of platinum catalysts.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

As indicated in 1. b and 2. d, significant operating prototypes can be available in 1990, with production available in ten to twelve years (on the present schedule).

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Work on this technology is being carried on in Japan, to some extent in collaboration with Hamilton Standard. US research is also being carried out on proton exchange membrane technology at Los Alamos and General Motors.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This technology can be exploited as soon as the decision to do so is made. Its maturation is consistent with projections for development of methanol as an alternative fuel. Either the fuel's advent will drive the technology, or the reverse will happen.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1982	LANL, GE
2. First Experimental Device application (or first experimental process demonstration)	1984	LANL
3. When available for inclusion in product or process?	1990	HS, GM

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The use of fuel cell technology for vehicle propulsion offers utility in all land vehicle applications as well as lightweight unmanned aircraft. Such usage would be coupled with electric motor drives. In addition, modular use of the technology allows part of the engine to be used as an onboard electric power source.

B. To what products or processes might it be applied?

See 3. A.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

A number of benefits would accrue from fuel cell technology's application to vehicle propulsion. First, the very large increases in efficiency allow for its use with alternative fuels, such as methanol. This offers a larger range benefit than improved internal combustion engine (ICE) efforts in the application of hydrocarbon fuels. Second, its very large efficiency increase allows for reduction in bulk fuel requirements even though a fuel with half the heat content is used. Third, a genuine modular propulsion capability can be utilized. Coupled with electric drive to individual axles or wheels, the propulsion system can apply power to several axles, or can drive the vehicle with part of the system inoperable. Since land and small air vehicles now operate with one propulsion system , the engine is a single point of failure. Allowing a time modular capability means this historic vulnerability to mobility kills is now significantly reduced, probably by a factor of two to three. Fourth, the proton exchange membrane cell has inherently very low signature capability. It operates silently, resulting in no acoustic signature. It has a very low operating temperature (see 1A), resulting in a low IR signature for the engine. And the exhaust is particulate free vapor of approximately 100°C exhaust temperature. This results in virtually no plume signature. Fifth, the modular capability of the cell allows for replacement of mobile electric power sources with part time use of one module of the engine, with concomitant reduction in auxiliary equipment.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

This technology, coupled with other signature reduction efforts, can make major impacts in vehicle signature characteristic.

REPORTER: Michael E. Montie

AIDED BY:

TECHNOLOGY: REDUCED OBSERVABLES [D-14]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Technology to permit assessment, design, and materials to permit reduction of airborne, ground based and sea surface targets in multiple wavelengths bands is emerging from research. Included are: (a) Broad Band Sensor packages that are capable of the acquisition of data that can be readily interpreted in terms of friendly and threat recon and target acquisition sensors; (b) Comprehensive mathematical models capable of predicting target signatures in dynamic realistic backgrounds; (c) Multi-spectral counter-surveillance materials for engineering application on ground and airborne targets.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Signature reduction techniques and materials must be incorporated into the vehicles in such fashion that the function of the vehicle is not impaired. Many methods are available to reduce signatures and user, developer and contractor expertise must be used in arriving at trade offs of effectiveness, function and costs. For example, application of signature reduction techniques and material could make the vehicle more difficult to de-contaminate in an NBC environment.

2- STATUS

. Describe the status of work at organizations which would be involved in developing this emergin̄ technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Substantial proof of concept for major parts of the technology is being demonstrated by all services. However, the decision as to when to use the technology on new or existing equipment is classified.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

This information is classified.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Vehicle survivability and effectiveness in a tactical environment is the primary driver. Production costs and strong service support will control implementation.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration Partial	1985	Army, AF, Navy
2. First Experimental Device application (or first experimental process demonstration) Classified		
3. When available for inclusion in product or process? Classified		

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Since materials evolving from this technology can be used as applique or structural materials, they can be applied to air, land and sea surface vehicles in a number of forms.

B. To what products or processes might it be applied?

Air, land and sea surface combat and support vehicles.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Reduction of vehicle signatures, land, air and sea surface, allow for reduced vulnerability of the vehicle at a given range. This permits vehicles to get closer to designated or desired target thus increasing offensive weapon effectiveness without decreasing their survivability.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Reduced detection/identification of vehicles greatly enhances vehicle survivability and battlefield effectiveness, this in turn enhances the military capability while decreasing logistic and maintenance burden.

REPORTER: Benn

AIDED BY: Wagner

Mick

TECHNOLOGY: ACTIVE CONTROL OF RADIATED SOUND & REFLECTED SOUND (TARGET STRENGTH) [D-(18,19)]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Machinery vibrations transmitted through hull structures constitute the major source of radiated sound for submarines. Active closed cycle cancellations of vibrational energy has the potential for complete elimination of harmonic tonals (10 dB to 20 dB reduction) and significant reduction in broad band energy (3 dB to 5 dB). The emerging technologies are in piezoelectric force transducers and in high speed closed cycle control systems. Active control reflected sound technology is emerging in broad band multi-layer coatings with piezoelectric matrix or composite structure. Submarine coatings with satisfactory hydrostatic strain characteristics and broad band noise reduction (reflected) are technologically sound and moving beyond the scientific principle stage.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Active vibration control has been demonstrated on laboratory scale. The sensor, control logic and force transducer must be fabricated on a self contained unit appropriate for machinery mount interface application to existing Navy equipment. Future machinery mount designs will include prefit control and vibration cancellati[illegible] mounts. Flow noise applications require the development of suitable broad band frequency control algorithms and low amplitude broad band force transducers. The major or keystone material for submarine coatings for active reduction of reflected sound is a material with low hydrostatic compressibility (zero frequency) but appropriate high frequency sonic absorption. Metal matrix coatings show promise in this emerging technology. The complete spectrum of adhesion methods for submarine coatings must be explored by fabricators to optimize the practicality of the concept. Large scale manufacturing of coating materials is technologically within our reach.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Active machinery mount vibration control is a near term technology (< 4 years) at the stage for product development. Active coatings have moved beyond the basic research/scientific principle state but are not yet ready for production (estimate 8 years)

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

The US is behind the UK and the FRG in the development of active control technology for machinery and flow generated (internal pipe flow) noise. The US has full scale demonstration vehicle capability. The US is probably on a par with the USSR in coating developments for active control.

C. *What needs/opportunities will drive this technology (e.g., costs, military,* industrial, consumer, environmental, etc.)? Be as specific as possible.

The need is to reduce radiated noise and target strength (sonar) of Navy surface ships and submarines. There appear to be no major commercial opportunities outside of the Navy. There are no environmental concerns and cost is a DoD mission concern.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale. Delphi results for D-18 and D-19 were the same
Value--1 vote for 4, Avail--1 vote for >05

MILESTONE	YEAR		BY WHOM	
	D18	D19	D18	D19
1. Proof of scientific principle demonstration	80	85	UK FRG	US
2. First Experimental Device application (or first experimental process demonstration)	84	89	UK	US
3. When available for inclusion in product or process?	90	95	US	US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

The security of Navy ships and submarines is dependent upon their capability to perform without radiating sound. The target strength of surface and subsurface ships will be reduced through the use of this emerging technology. All ships will benefit and the technology has promise for application in counter measure situations. Both technological applications have the potential for sonic signature construction as well as signature reduction.

B. To what products or processes might it be applied?

Active vibration control will be applied to all rotating machinery mounts and appropriate flow control devices. Active sonic absorption coatings will be applied to submarine hulls, surface ship hulls, propeller ducts, rudders and other stability and control devices, pipe flow transitions and possible internal ship applications. Both technologies have far reaching non-military product applications and multi-service military applications.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Reduced radiated sound translates into increased survivability. Practical results are higher speed capability, reduced detection range, increased sonar capability due to reduced self generated noise.

Reduced target strength allows greater mobility and operation closer to attack forces.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The security of our strategic undersea forces is directly dependent upon the level of detectability of each individual ship. The radiated self generated noise and the reflected noise target strength determine the limiting condition of operability for these ships. Reductions in sonar detectability, either passive or active, allow an expansion of the operating conditions for these forces. Increased self sufficiency on the part of the undersea forces may reduce their dependence upon the surface ASW forces.

The general need for vibration control is applicable to all machinery systems. Army mobility systems and vehicles will benefit from the product. Synergistic developments in commercial and military fields will result in reduced size and weight of active vibration control devices.

REPORTER: --

AIDED BY: D. D. Moran

TECHNOLOGY: HIGH TEMPERATURE NON-METALLIC MATERIALS--APPLICATION OF NOVEL PROCESSING METHODS AND SCIENCE [I-(3,9,12,16,17,20)]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

In the past few years the breadth of available processing science and technology has expanded considerably. Improved and alternate methods of producing raw materials of higher purity [e.g. Laser techniques to produce powders and a host of other possibilities], novel processing routes to control additives [e.g., chemical approaches to form high purity polymers and ceramics and their composites, etc.], use of environmental extremes [e.g. expanded ranges of pressures, temperatures, more precise controls of gaseous mixtures, etc.] and the introduction of advanced or unique performance materials into the manufacturing process itself are representative areas of the available emerging technologies. The basic notion of this activity is to systematically apply innovative approaches to the broad range of high temperature non-metallic materials. This encompasses inorganic polymer systems, ceramics, and their composites, such as carbon-carbon materials. Novel methods of preparation of large single or poly crystalline materials, usually prepared as ceramic, such as SiC and AlN are included. Cost reduction and enhanced performance are the motivators.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Within the Federal laboratory complex, more than 10,000 (?) researchers are actively engaged in material development, and the whole military industrial complex probably spans more than 50,000 major as well as small businesses. Surveys of possible advanced processing technology applications should be better coordinated and continually updated and better financed on a long term basis. (See STATUS comments.) Professional societies could aid in these assessments. Long range DoD and other federal laboratory plans could also be reviewed via appropriate procedures.

2- STATUS   SEE ATTACHMENT

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)		
3. When available for inclusion in product or process?		

HIGH TEMPERATURE NON-METALLIC MATERIALS--APPLICATION OF NOVEL PROCESSING METHODS AND SCIENCE [I-(3,9,12,16,17,20)] cont'd

2-STATUS (attachment)

Currently maneuverable small scale, generally uncoordinated efforts in novel processing are occurring across the nation, indeed around the world. However, in the international communities, Europe and Japan in particular are attempting to capitalize on high technology materials. These are planned long term programs which are generally fully vertically integrated with government, industry and university participation on a targeted basis. The Japanese MITI, for instance, is aggressively seeking to expand their economy and institutionalize a high volume, low cost, high tech materials production capability. The DoD materials funded effort rarely provides the basis for economical production of their significant materials. In the meanwhile the typical US contractor seeks to profit by the promising laboratory scale demonstration of what might be termed exotic materials. Little consideration is given on a national front to produce these high performance materials on a low cost basis, or to truly build an internationally competitive production base. Considering the available resources in the US, a well coordinated introduction of novel processing science methodologies would have an enormous impact on our gross national product, balance of trade and economic well being in general. It would constitute regaining our industrial dominance.

Summary of the Delphi inputs serves to show the very incomplete and generally low quality input received. In depth status reports and input should be prepared. [At least a brief summary of DoD/NASA 1498 abstracts, IRAD studies, etc.]

Summary of Delphi inputs [I-(3,9,12,16,17,20)]

	Value 0	1	2	3	4	Availability -85	-90	-95	-00	-05
° Fiber Reinforced Ceramics [I-3] Round 2		1	6	23	19	1	16	15	8	
Round 3				7	3	1	2	5	1	1
°Novel Methods of Preparation of Large Single or Poly Crystalline Materials [I-9] Round 3		2		1	1		1	2	1	1
° Practice of Attainment of High Temp Ceramics, etc. [I-12] Round 3			2	1	2		2	2		1
° Inorganic Polymer Systems, etc. [I-16] Round 3			2	2			1	1	1	1
°Oxidation Resistant lightweight composites for performance above 3000°F [I-17] Round 3			1	2	1			3		1
° Chemical approaches to formation of high purity, crack resistant ceramics [I-20] Round 3			2		1		1	1		1

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Broad scale improvements of a wide range of DoD materiel quite large in scope--beyond mobility into logistics (life cycle costs, reliability, etc.). This emerging technology can be applied to product improvement as well as advanced concepts. It is readily understood that unique materials performance is a cornerstone of many military systems.

Also see page 4A.

B. To what products or processes might it be applied?

See above.

Also see page 4A.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Utilization of emerging materials processing science is critical to superior weapons capabilities. Expanding performance limits and operational mission capabilities are intricately tied to this technology.

(see page 5A)

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

REPORTER: E. M. Lenoe

AIDED BY: W. Bryzik

[I-(3,9,12,16,17,20)] HIGH TEMP NON-METALLIC MAT'LS

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Lenoe's statement seems a good global introduction; add the following:

The development and application of these technologies will substantially contribute to vehicle capability (improved performance), survivability (ability to dissipate emissions), availability (more survivable systems and better raw mat'l availability and affordability (in the long term the finished cost of non-metallics should be less than metallic counter-parts--some of which are presently classified as strategic mat'ls).

B. To what products or processes might it be applied?

High temp non-metallic mat'l technology will first be applied to propulsion systems (combustors, turbines, augmentors, exhaust nozzles, hot frames and jet pipes). These mat'ls are required to advance power-to-weight or thrust-to-weight ratios over current systems. If one predicts where Fn/wt improvement will come in a modern transonic/supersonic aircraft application, there are gains in component efficiencies, increases in cycle temperature, reduction in parasitic or secondary losses and improved temp or strength-to-weight mat'ls. By far the largest near-term impact is in innovative materials development. Consider the turbofan/turbojet propulsion system: Current Fn/wt.7/8:1; 1995 Fn/wt 10:1; 2010 Fn/wt 12/15:1. A limited number of composite components are required to demonstrate 10:1. Considering a 12/15:1 level of technology, a significant new contribution in Hi temp/light

(cont'd below)

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

In 3.B. we discussed barrier technologies with respect to the propulsion system. Consider also a significant performance gain to the weapons systems platform in terms of non-metallic, lightweight, high strength mat'ls--payoff is in terms of total capability (performance, Ps, turning rate, trade flexibility, i.e. payload/range). For example, current weight fraction (tactical system) is approx. 45% of total TOGW. To predict major gains 1) lighter A/C, 2) more fuel, or 3) more payload--platform weight must be reduced.

(3.B. cont'd) weight materials is required. Cycle and turbomachinery advances will tend to peak-out and going beyond 15:1 will require significant application of both materials and fuels technology. An example of payoff, consider a system requirement with a given payload, fuels stores and vary engine Fn/wt and A/C TOGW for a given mission. Using a 25% gain in engine Fn/wt over today's systems reduces A/C TOGW by 5000 #.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

GENERAL SUGGESTIONS:

Non-metallic/composite mat'ls are emerging across the board (applications)
Hi temp is relative, consider gains in A/C structure, i.e., composite wing or F404 engine fan duct suggest changing title to Hi temp/Hi Strength non-metallics. Also, suggest bringing in or tieing Hi temp coating i.e. C14 (Carbon/Carbon won't meet application without adaptive coating.)

REPORTER: Dave Moran (?)

AIDED BY:

MOBILITY

TECHNOLOGY: CONTROL OF VORTEX FLOW FOR BOTH AIR AND UNDERWATER APPLICATIONS [H-(2,9)]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

This technology involves the formation, control of trajectory and elimination, when desired, of the vortices shed from aircraft forebodies wings and control surfaces. In submarines, the rise, dive and roll in a turn results from lift generated through flow separation and is manifested in high strength vortices. These vortices impact downstream control surfaces, beneficially or adversely depending upon relative locations, and in submarines adversely affect propulsion. In underwater applications, this can result in increased sonic signature and has high potential as a surface observable. Control of these vortices is achieved thru deflection of mechanical flaps--vortex flaps--and thru spanwise or tangential blowing at critical locations.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Since the addition or subtraction of momentum through blowing at local critical areas is one method emerging to create and control the vortex shedding process, the fabrication of small, variable aspect ratio nozzles and/or the precise drilling of a matrix of blowing/suction ports is required--a capability which is at hand. The critical items to mature this technology are to define the location and extent of momentum modification required to achieve the desired vortex flow. The resulting structural and dynamic loads must then be determined for the operational aircraft.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Technology should be available in the 1990-1995 time frame.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Based upon available technical papers from NATO and Russian literature and direct working knowledge of US activity, the British, French and Russians are also involved in this research, all four in air and the US and Soviet Union in underwater applications. We estimate the US to be slightly ahead of the field in research and technology application, for both air and underwater appl.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

The need for fighter-type aircraft to maintain controlled flight during maneuvers at high angles of attack ($\alpha > 20°$) in air combat, plus quieter vehicles underwater are the driving need for this technology. System weight penalties and associated costs; however, are still to be addressed.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1982	NASA
2. First Experimental Device application (or first experimental process demonstration)	84-85	NASA
3. When available for inclusion in product or process?	1990-95	US

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Control of shed vortices can result in:

- Enhanced lift by maintaining attached flow and delaying separation
- Reduction or enhancement of forces and moments to reduce trim or increase control and maneuvering
- Departure-free flight
- Modification of vortex path to avoid disruptive interaction with control surfaces
- Reduced hydrodynamic generated noise

B. To what products or processes might it be applied?

Swept wing aircraft
Oblique wing aircraft

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Vortex control will enable departure free maneuvering capability of fighter aircraft, enabling higher levels of turning rates, pointing capability for weapons delivery and controlled flight in the post-stall region--all of which increases effectiveness of dogfighting capability.

In underwater, faster, quieter and more maneuverable submarines.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Vortex control combined with thrust vectoring will provide even greater maneuverability using thrust vectoring to maneuver aircraft and vortex control to maintain attached flow on control surfaces for effective control.

REPORTER: Marvin Walters

AIDED BY: David Moran

Ray Rose

TECHNOLOGY: SUPERSONIC COMBUSTION FOR HIGH MACH NUMBER AIR BREATHING PROPULSION [H-4]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

- Enabling technology for sustained flight speeds above mach 4.0.
- Variable engine inlets being developed for hybrid engines (jet/ramjet combinations), potential operation to mach 5.0.
- ICFD techniques should offer insight into internal combustion analysis and fundamental kinetics.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

- Must determine high temperature materials required.
- Must be able to predict or characterize
  - internal flow characteristics
  - fuel distribution/mixing
  - flame speed (residence time)

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

- ° Advanced, efficient supersonic transports estimated for year 2000. Supersonic combustion technology, 1990-1995.
- ° Ramjet, for mach 3-7 missiles (external acceleration), 1990-1992.
- ° Hybrid systems (self acceleration), approx. 2000.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

In open literature, US is sole performer. However, need intelligence source to determine non-US involvement.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Required military missions will drive this technology:

- Need for sustained supersonic/hypersonic flight
- Missile applications

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration Net positive thrust	1980	NASA
2. First Experimental Device application (or first experimental process demonstration) Inlet Combuster Nozzle	1986-87	NASA
3. When available for inclusion in product or process?	1990-92	?

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

- Aircraft requiring sustained supersonic/hypersonic cruise.
- Various missile configurations including boosted, standoff missile configurations with mach 5-7 capability.

B. To what products or processes might it be applied?

High speed flight vehicles--aircraft, missiles, etc.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

- This technology would result in an expanded military fleet defense perimeter.
- Enhanced SR

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

The development of the high temperature structures and design integration could yield a revolutionary expansion of the available operational military flight envelope.

REPORTER: Ray Rose

AIDED BY: Roger Winblade

MOBILITY

TECHNOLOGY: AUTOMATED VISION [L-(1.2)]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Refers to the means for permitting a machine to mimic or emulate the human function of vision, visual perception, object recognition and classification, and the abilit to base decisions thereon. Includes capability of a machine to discriminate a 3-dimensional object as an item of interest from a scene consisting of other 3-D objects and surfaces. Very similar to character recognition but much more difficul due to additional dimension and presence of other objects in view field. Derives depth perception through stereoscopic means or other physical wave signal processin means. Ability to classify based on pattern/form recognition.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Requires pattern recognition algorithm development based on image data and expert system technique which captures human treatment of surface and edge connectivity to discriminate objects in visual perception. Very large, fast, parallel processin computers will be needed to implement. Practical applications.
Requires image processing algorithms to reject spurious signals.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

DARPA is sponsoring autonomous land vehicle demo. Army and NASA are pursuing research.

Current approaches can only handle simplified applications. Serious applications should be expected after 1995. Processing capability cannot keep pace with practical vehicle speeds.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Really an emerging technology. Nobody has a clear lead at present.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Industrial/consumer applications will pace the rate of availability due to profit motive.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980-85	US Academia
2. First Experimental Device application (or first experimental process demonstration)	1990	US Ind. Labs
3. When available for inclusion in product or process?	1995	US Ind.

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

To be used potentially in surveillance, security and national defense early warning applications.

B. To what products or processes might it be applied?

Surveillance systems. Automatic patrol and guard functions. Autonomous vehicles on ground. Aircraft collision avoidance systems.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Military impact: Manpower savings in automatic surveillance systems and increase in coverage of space on volume under surveillance.

8. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Profitably combined with robotics applications. As a force multiplier that does not tire or require sleep.

REPORTER: Arnold Mayer

AIDED BY: Bob Benn

TECHNOLOGY: MAN-MACHINE INTERFACE [L-(4.20)]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Refers in teleclogical terms to the technology necessary to design, allocate functions and control the symbiotic interplay of the human component and the machine of high performance man-machine systems. Specifically includes electro encephalographic(EEG) based sensors to monitor the state of alertness and vigilance of the human component; effectors to stimulate attention visually , audibly, tactical/sensorily; or electrically Control laws to adaptively allocate decisions or action functions to the human or machine depending upon workload-relative-to-capacity measures; design methodology for optimal system architecture to retain overall system property of human reasonableness and reversibility. With the machine component accounting for limitations in human capacity or stress (physical or mental) tolerance.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Prior developments required include additional characterization and understanding of human working capacity in relation to mental effort under stress and their correlatic with EEG brainwave signatures or other physiological chemical/electrical signatures. Measures of man-machine architecture and performance optimality need to be defined. Algorithmic design efforts are required. Man-machine modelling, simulation, and evaluation technology needs development. Developments in AI, expert systems, user friendly computer interfaces, voice recognition, activation, speech generation and robotics will be useful.

The capability of learning machines for eventual transfer of functions to all machine operations or for pilots of variable expertise when required will prove useful.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

Work load capacity measurements have been undertaken by the Air Force, Army, Navy, and NASA. Wright State University, Ohio has demonstrated the restoration of muscular activity capability through electric stimulation of paralysis victims.
A critical mass of technology for major capability increases may be expected by 2000 but incremental improvements will occur sporadically before then.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

Rough parity exists on an overall basis between US and foreign capabilities. It is believed that Soviet understanding of human physiological and psychological behavior is slightly superior but that US and Japan enjoy the lead in computers, automatic control, displays, and simulators.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This technology is paced by availability of fundamental knowledge about human intellectual/decision making, reasoning capacities under stress and high workload. Commercialization is favored by availability of simulators to provide context related evaluations of man-machine system design and performance.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	by 1990	US
2. First Experimental Device application (or first experimental process demonstration)	by 1995	USAF/NASA
3. When available for inclusion in product or	by 2000	US Indust

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Could be used for optimal workload allocation and mission adaptive function allocation in cockpit of supersonic/hypersonic manned venicle, tanks and mobile field command posts.

B. To what products or processes might it be applied?

High performance military aircraft cockpits in combat and penetration. Military Mobile Command Centers. Strategic Defense. Commercial Airliners.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Military impact would be highly survivable, lethally effective force application. Qualitative weapon system superiority over adversary. Conservation of human resources and acceleration, and reduction in training requirements.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

Payoff is maximized when integrated with vehicles capable of post-stall maneuverability and hypervelocity as a consequency of airbreathing supersonic combustion propulsion systems and 3000-5000°F high temperature tolerance materials. Should be combined with sensor and display mediated means of alternate or automated vision for assimilati[illegible] by humans.

REPORTER: Arnold Mayer

AIDED BY: Stan Sadin

TECHNOLOGY: SPEECH UNDERSTANDING [L-(6,7)]

I- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

General speech understanding as a machine capability is just barely an emerging technology. Specific commercial products are available which allow a single human to "train a machine to "understand" a small set of spoken words or (short) phrases. These commands can then be used to trigger responses. The growth problems at that level include increasing vocabulary understood from tens of words to hundreds of words in domains that are unambiguous in terms of overlapping meanings. Obviously, then, growth must attack the problems of multiple domains, continuous speech, speaker independence, and background environments of increasing harshness and noise. This will require a high degree of natural language understanding based upon more than syntactic recognition, including also semantic and pragmatic recognition of standard prose. The degree of inferencing capability of current expert system technology ($\sim$ hundreds of rules) is insufficient. An order of magnitude increase in inferencing power should handle continuous speech in a domain of several hundred words that is speaker dependent. Very powerful heuristic approaches to algorithms will be required to go beyond that.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

This technology will be producing products of incremental capability for ten to 15 years before all areas are adequately covered.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

See 1.B.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

There is work being codirected in Japan, Europe, and the Soviet Union, though I'm not qualified to assess their progress.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

This capability is heavily dependent upon concurrent development of expert system and computer processing technology.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration		
2. First Experimental Device application (or first experimental process demonstration)	1983	TI
3. When available for inclusion in product or	open ended	

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

Speech understanding is a capability that has obvious potential as an I/O capability for any automated/directed activity applicable to mobility. These include vehicle control, troubleshooting, remote addressing, onboard equipment (to include weapons) employment, and record keeping. This technology is applicable to all types of vehicles (air, land, sea, and space), and can, in conjuction with other technology, result in more responsive systems requiring fewer people. While not needed for autonomous operation, voice understanding can contribute to reductions by a factor of two in system crews for vehicles and weapons systems.

B. To what products or processes might it be applied?

See 3.A.

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Beyond that described in 3, it is difficult to quantify the impact of speech understanding. It is a technology that will contribute to a range of improvements that will mainly impact on force structure requirement reductions, but generally will not of itself produce other quantifiable results.

B. What synergistic effects might this technology have on US military capabilities when combined with other technologies?

I believe this is adequately described in previous sections.

REPORTER: Michael E. Montie

AIDED BY:

TECHNOLOGY: ROBOTIC TASK MANIPULATORS FOR MOBILITY SYSTEMS [L-13]

1- DESCRIPTION

A. Describe the emerging technology in quantitative rather than qualitative terms to the extent possible. Descriptions such as "high power" or "low loss" are insufficient.

Laboratory research has demonstrated the feasability of robotic task manipulators for mobility systems which are capable of emulating and exceeding human dexterity, precision, and strength in the conduct of tasks not suitable to humans for reasons of safety, accessibility, performance, or cost. Capabilities include: multi-fingered end-effectors; six degree of freedom motion; force and visual sensing and control; work positioning combined with task-performing robot arms; multiple arm, shared task performance; and automated sub-routines for fully predictable and/or repetitive task performance.

B. List and describe related manufacturing know-how, keystone equipment or materials, etc., which would be necessary to translate this technology into large-scale production, or apply it to production processes.

Current capabilities in so-called robotics systems are limited to fully programmed, position controlled, two digit (mitten-like) robot arms. Slightly more sophisticated devices have been produced for surface, air, space, and underwater vehicle applications. But the known potential capability is far from realized. Laboratory research has demonstrated this potential in the government, industry, and university sectors. Key disciplinary advancements include: sensing and control; computational hardware and software; and expert systems logic.

2- STATUS

Describe the status of work at organizations which would be involved in developing this emerging technology:

A. Estimate time availability of the technology (i.e. when will it be available for inclusion in a product or production process?).

This technology could be made available in advancing levels of capability beginning as soon as five years, with dramatic results emerging in ten years and extensive applications likely in a 15 year time frame.

B. Estimate US status compared to any non-US work being done on the ET in question/ or its inclusion in a (ours and theirs) defense system.

US laboratory research investment is considerable and extensive by comparison with non-US activities. The Japanese reputation in robotics is earned only for their application of research by others (principally US) to simplistic, programmed, task performance. They will continue to tap US research and compete for the rewards of translating it to emerging applications. The Europeans would do the same if they could.

C. What needs/opportunities will drive this technology (e.g., costs, military, industrial, consumer, environmental, etc.)? Be as specific as possible.

Remote manipulator vehicle capability for reconnaissance, inspection, assembly, deploymen arming, disarming, recovery, repair, replacement, and resupply for ground, air, sea, underwater and space operations.

D. Use the tabular form below to identify important milestones in the emergence and development of this technology. Copy the relevant information from the Delphi results. If your session disagrees, please state so, with rationale.

MILESTONE	YEAR	BY WHOM
1. Proof of scientific principle demonstration	1980s	DoD, JPL NASA, DARPA
2. First Experimental Device application (or first experimental process demonstration)	1990-1995	NASA/ DARPA
3. When available for inclusion in product or	1995 -2000	Gov't Industry

3- APPLICATIONS

Describe the potential military applications of this ET:

A. How might it be used?

1. Spacecraft assembly, service, repair, and resupply
2. Underwater exploration, mining, drilling, service repair
3. All-terrain vehicle for hazardous task performance e.g. mine sweeping, damage assessment
4. Nuclear operations
5. Remotely piloted aircraft

B. To what products or processes might it be applied?

-- Deep sea operations
-- Hazardous field tasks
-- Deep sea operations
-- Air to air refueling, maintenance, repair

4- IMPACT

Estimate the potential military impact of this technology:

A. How might the technology in question change US military capabilities?

Provides the capability to perform operations in otherwise inaccessible or hazardous environments and to perform tasks that exceed human capabilities of strength, endurance, precision, and repetition. Impact on SDI space-based architectures and their cost-effectiveness is estimated at near 50%. Civil space-based activities, as their scope and scale expands, should be similarly impacted. Ground and sea operational limitations to military missions requiring human presence can be mitigated by use of task performing robotic manipulators.

8. **What synergistic effects might this technology have on US military capabilities when combined with other technologies?**

The technology contributes to both teleoperated vehicle systems and to autonomous vehicle systems development. Synergistic technologies include automated vision, man-machine interface, automated speech recognition and understanding, machine intelligence and expert systems. The probable sequence of applying these synergistic technologies is first to teleoperated vehicles wherein a remote human presence provides the executive control functions in task performance. With the later emergence of autonomous decision-making capabilities, authority could gradually shift from humans to smart machines and create near-human surrogates for dramatic expansion of US military capability.

REPORTER: S. R. Sadin

AIDED BY: A. H. Mayer